INDIA-RUBBER
AND·ITS·MANUFACTURE

HUBERT·L·TERRY·F·I·C·

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INDIA-RUBBER AND ITS MANUFACTURE.

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AND ITS MANUFACTURE

WITH CHAPTERS ON GUTTA-PERCHA AND BALATA

BY

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PREFACE.

The largely-extended use in recent years of india-rubber tyres on vehicles of all sorts has led to an increased interest being taken by the general public in the natural history and manufacture of rubber. Moreover, the establishment within the last year or two of numerous rubber plantations in Ceylon, the Straits Settlements, and Malaya has led to this almost indispensable commodity becoming a common topic of conversation.

The present volume, therefore, which is expressly designed for the general reader and for the technologist in other branches of industry, cannot be considered a superfluity—that is, if its scheme of bringing information up to date is considered by the critical reader to have been accomplished. It may be as well to state emphatically that this small volume does not pose as a working guide or hand-book for the india-rubber manufacturer, though it is hoped that the latter may find something to interest him in its pages. Success in the manufacture of india-rubber goods, I am well aware, depends largely upon close observance of detail. Except to the somewhat limited circle of manufacturers such points of detail have no interest or significance, and I have therefore avoided digressing into them or attempting to shed light on the numerous problems in the manufacture which, despite the energies of an increasing body of investigators, still await solution. Naturally, I

have had frequent occasion to refer to the works of previous authors, and I wish to express my indebtedness to Messieurs E. Chapel and G. Lamy-Torrilhon, of Paris, Herr F. Clouth, of Cologne, and Mr. H. C. Pearson, of New York, as well as to the publishers of Dr. Weber's book. To the Editors of the *India-rubber World* and the *India-rubber Journal* I am particularly indebted, as it would be a vain task to attempt to bring the subject up to date without frequent reference to the files of these journals. A certain amount of the subject-matter has appeared during the last ten years or so in the form of articles in the technical Press. In every case the article has been entirely re-written, but I have to acknowledge the courtesy of the Editors of the *India-rubber World*, the *India-rubber Journal*, *The Engineer*, *Engineering*, *The Electrician*, and the *Electrical Review*, for their permission to republish.

With respect to the subject-matter, my best thanks are tendered to Colonel R. K. Birley, C.B., V.D., for reading through the manuscript, and to Mr. A. E. Walker for much information regarding raw rubber. For the botanical illustrations I am indebted to the pen of Mr. H. F. I. Incledon-Webber, except in the case of Fig. 1, which is from a photo given me by Mr. C. B. Cowper-Coles. Figs. 2, 4, and 5 have been reproduced from the *Indiarubber World* by the kind permission of the Editor. For the machinery cuts I have to express my obligations to Mr. J. Iddon, M.I.Mech.E.

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CONTENTS.

ILLUSTRATIONS.

INDIA-RUBBER.

CHAPTER I.

INTRODUCTION: HISTORICAL AND GENERAL.

India-rubber, or caoutchouc, is the name commonly given to the milky latex occurring in the bark of certain species of trees. The latter term is variously derived by authors from the vocabularies of South-American Indians, but it is not proposed to say anything here on the point. In this work the common English name of "india-rubber," or, more shortly, "rubber," will alone be employed, though having regard to the multifarious uses to which the substance is now put, this old name, which bears reference to its original use, cannot be considered an ideal one. In America and on the Continent the term "gum," or its foreign equivalent, is commonly used—a practice which has little to recommend it, and, indeed, is decidedly objectionable as tending to confusion with the real gums which are soluble in cold water. Still, the American "gum," the German "gummi," the French "gomme elastique," the Italian "gomma elastica," and the Spanish "goma elastica," bear testimony to the extent of its adoption.

With regard to the history of its introduction into Europe, the little that is known with certainty has been

said so often, and allows such small scope for elaboration, that merely a few words will be sufficient. Two or three Spanish authors in the sixteenth and seventeenth centuries referred to games played by the natives of South America and Mexico with an elastic ball obtained from the white exudations of certain trees. It was reserved, however, for the French travellers, De la Condamine and Fresnau, to make known to the scientists of Europe the nature of the substance and the various uses to which they found it applied. This was during the years 1731—1736, and it was soon after experimented upon by French chemists, and also by the English chemist, Priestley, who is credited with the proposal to use it for effacing pencil marks. In 1791, Samuel Peal took out a patent for waterproofing cloth by brushing the hot rubber on it, and in 1813 John Clark dissolved rubber in turpentine and applied the solution to the manufacture of air beds.

It was not, however, until 1820, when Charles Macintosh, F.R.S., of Glasgow, proposed the use of a solution of india-rubber in coal-tar naphtha for the manufacture of waterproof garments, that the substance became important as the raw material for an industry. Macintosh entered into partnership with the Messrs. Birley, of Manchester, and the year 1823 witnessed the foundation of the pioneer firm of Messrs. Charles Macintosh and Co. in an industry which was destined to have such great developments in succeeding years. This firm is still in the forefront of the trade, and although numerous extensions have been made to the premises, the original building in which the first rubber-spreading machinery was erected is still being utilised for the same class of work. With regard to

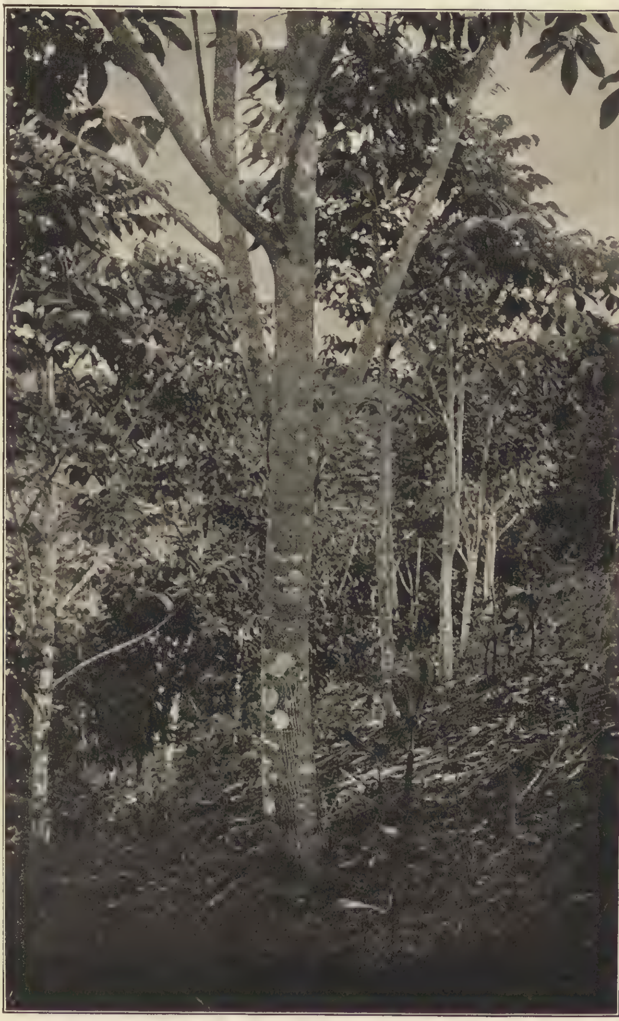

FIG. 1.—CASTILLOA ELASTICA. LAS CASCADAS PLANTATION, PANAMA.

actual priority of manufacture, there is very little between Charles Macintosh and Thomas Hancock. The latter was in the year 1819 energetically pursuing investigations on india-rubber, and if it had occurred to him to use naphtha instead of turpentine, a well-known article of clothing would doubtless have received some other name than that by which it is so universally known. In other respects, however, in its influence upon the development of the trade, Hancock's work as regards the mastication and vulcanization of india-rubber was of far greater importance than was Macintosh's, and a business arrangement was formed in 1826 between Hancock and the Macintosh firm at Manchester for their mutual advantage. The former's original factory in Goswell Road, London, is still carried on by his descendants, and can legitimately be called the oldest factory in the trade, though, as far as vulcanized rubber is concerned, that distinction belongs indisputably to Charles Macintosh and Co. Those who would know more of Hancock and his work will find it fully treated in his "Personal Narrative of the Origin and Progress of the India-rubber Manufacture in England," published in 1857. It indicates the indomitable perseverance with which he applied himself to the solution of baffling problems, though naturally in the advanced knowledge of these later times it is not always easy to appreciate the disabilities under which the forerunners in this industry laboured, or to make due allowance for their failure to grasp the significance of what we have come to look upon as obvious. The book has, of course, been long out of print, and many will, therefore, probably find it difficult of access. Hancock's first important discovery was that scraps of pure rubber

could be made into a solid block by mechanical action. In this form the rubber could be cut into sheets, and it was at once recognised that the discovery would have an important bearing upon its applications. The "masticator," or "pickle," by which latter name Hancock called the machine he had invented, only produced blocks of a few inches in length and breadth, but in principle, as we shall see in a later chapter, it has undergone very little change in the course of its existence, except in increased dimensions and capacity. No patent was taken out by Hancock for his machine, and it was kept a secret for twelve or thirteen years until a workman divulged its details. Having obtained a licence from Macintosh to work his patent, Hancock soon found that in his masticated rubber he had an advantage over the Manchester firm, as he could make a much stronger solution with the same quantity of naphtha. It was this fact which led to the business arrangement already notified as having been entered into in 1826 between Hancock and the Macintosh Company at Manchester. During the next twenty years, although business proceeded steadily, no particularly rapid progress was made in applying rubber to the needs of the arts and manufactures. This was due to the fact that it was affected so largely by heat and cold, and it was not until after 1844, when the discovery of vulcanization had been made, that the manufacture showed any considerable expansion. It is impossible to exaggerate the importance of the vulcanization process; without it, it is clear that the industry of to-day, subserving as it does so many of the needs and fancies of mankind, could never have attained to its imposing dimensions.

Since 1845, although the new applications of vulcanized rubber have been numerous enough, there has been no discovery of any revolutionary character in connection with the manufacture, progress having been pretty generally confined to improvements in the processes and plant of sixty years ago. A momentous advance has been made, however, in the way of reducing the amount of rubber in some classes of goods to a negligible quantity, but this sort of progress has very dubious claims to consideration. It has been contended that for the last fifty years there has been no discovery of a revolutionary character as far as the manufacture is concerned. Exception may be taken to this dictum by those chemists who have credited Mr. Kelway Bamber with having inaugurated a new era. Mr. Bamber has recently proposed to vulcanize the coagulated rubber in the precincts of the plantation or forest with chloride of sulphur in order to prevent the fermentation of albuminous matters during transit to Europe, but the nipping in the bud here proposed is likely to create fresh evils of greater potency than those it is sought to eradicate. Perusal of the following pages will make it abundantly clear that rubber goods are made in a variety of ways, and in the majority of cases from a mixture of materials; moreover, the vulcanization is always one of the final processes in the manufacture, and it is difficult to see the value of the proposal.

As already stated, the French scientists were the first to make the substance and its properties known in Europe, but the credit of establishing the rubber manufacturing industry belongs to Great Britain, though it was not many years after the commencement that works were started in

France, Germany and America. At the present time, in addition to these countries, we find factories in Austria-Hungary, Italy, Holland, Russia, Denmark, Norway, Sweden, Belgium, Switzerland, and Portugal, as well as in Australia and Japan. The term "india-rubber works" is, however, a very comprehensive one, some of the concerns being quite small ones, limited both in their output and as to the nature of the goods they manufacture; others of imposing dimensions are occupied almost entirely in one class of production, for instance, goloshes; while others, again, may turn out practically all the rubber goods which have so far been introduced. The qualifying term "practically" is used of set purpose, because the author is not aware of any factory where rubber goods of all kinds are manufactured. There are large concerns in existence where the omissions are extremely few in number, and these may be attributed either to want of room for the necessary work, or to a feeling that the branch does not offer sufficient pecuniary profit for the risk of the capital. In one or two branches specialisation may be attributed largely to the fact that the details of the processes involved are by no means generally known, and that skilled supervision and labour would be with difficulty obtained by new firms wishful of competing with old-established ones in some special branch of the trade. For example, until comparatively recent times, two or three large English works supplied the requirements of the world as regards fine-cut sheet and elastic thread, and their status in the markets still remains. From America, France, Italy and Germany, however, competition has now to be met, with the consequence of diminished profits. The tendency in the large European works has been to make all sorts of

goods, while in America specialisation in particular branches has been the general rule. The advantages of specialisation in the way of getting out quantity at a minimum expense are well known; its disadvantage lies in the fact that any decreased demand may rapidly bring about financial trouble. Where a factory makes all classes of goods a falling off in the demand for any one of them does not make itself so severely felt. In this respect, on looking back into history, we have to note the great falling off in the demand for elastic thread for shoe elastic; the manufacturers, however, soon found expansion in other departments to make up the loss of trade. In quite recent times we have witnessed the decline of the macintosh as a popular article of apparel. As a number of firms were engaged in this branch only, it is not surprising that several have entirely closed their works. The plant and machinery did not permit of their being put to other purposes, and taking up an altogether new branch, such as the manufacture of pneumatic tyres, meant the employment of a much larger capital.

If one can correctly gauge the pulse of the trade the tendency of the near future will be to close existing works rather than open new ones. The volume of trade has of course increased, but it is the general complaint that too much competition exists, and this not only in Great Britain, but in leading Continental countries. Despite the great access of business resulting from the increase of motor vehicles, existing factories have managed to cope with it, with or without extension of premises. Germany, alone, has about sixty india-rubber factories, many of the leading firms of the Fatherland, as well as those of other countries,

having offices and agents in London. With the advent of new countries into the manufacturing arena the foreign market for the older-established ones becomes more and more restricted, a specific instance of this being the large decline of German exports to Scandinavia since Norway and Sweden started their own rubber factories a few years ago. That the manufacture has advanced beyond requirements in Austria is testified to by the recent formation of a manufacturers' union, one of the objects of which was the concentration of certain classes of work in particular factories. The fact that with the great rise in the price of the raw material there has been a steady increase in the volume of the business done in manufactured goods is eloquent testimony to the recognition of rubber as a necessity rather than a luxury. Nor must this increased demand be considered to have emanated from one source only. There is a tendency to give the motor tyre the sole credit for the recent expansion in the rubber industry. This article perhaps comes more before the public eye than is the case with many others; but though, of course, the tyre is responsible for much of the increased business, a great deal of rubber goes nowadays to places where it is concealed from the public vision. For instance, in a modern man-of-war, besides the engine valves and washers, there is the large number of armour plate bolt washers, the use of which is enjoined by modern practice. To these must be added stair treads and mats and various other articles which come from the mechanical goods department of the rubber works. Then the electric cable industry must not be overlooked; but not to follow this topic further, it will suffice to say that the increase in the demand is a very

general one from a variety of sources, and this under the prevailing conditions of price must be taken as a good augury for trade prospects for some years to come at any rate.

A word as to the mechanical power used in rubber factories may not be without interest. Although the great bulk of the factories employ steam power, this has been replaced in recent years by electrical power in several cases, and with very satisfactory results. As far as Great Britain is concerned, this innovation is only to be found in two or three factories, of which that of the Leyland and Birmingham Company invites special mention. The current was installed in 1888. Besides the heavy rubber machinery, many of the smaller machines are run by motors fixed in the various workrooms. Electric power has also been used for many years in the rubber department of Messrs. Siemens' cable works at Woolwich, and is now installed at the works of the Avon Rubber Company at Melksham, and at the St. Helens Cable and Rubber Company of Warrington. Of Continental firms using this source of energy, the large factory of Pirelli et Cie at Milan may be mentioned. And in America electrical driving is employed in the new factory of the United States Rubber Reclaiming Company at Buffalo, the current being obtained from Niagara Falls. As electrical power has such an advantage over steam in the ease and economy with which its transmission in the factory is effected, we may expect to see it more largely adopted in the future. Water power as the direct source of energy is not unknown in the rubber factory. In France, at the works of Torrilhon et Cie., at Clermont Ferrand, the washing plant, which is situated at

a short distance from the main factory, is driven by a water-wheel. This is a special instance where local conditions are advantageous, but in a general way water power cannot be considered as suitable for a rubber factory, because of the great variations in the power required for different brands of rubber on the mixing rolls. The steam turbine of the De Laval type has been advocated by American engineers as suitable for rubber factory driving, but details of any installation are not yet to hand.

Hygiene in the Rubber Factory.—Reference is made elsewhere to poisoning by carbon bisulphide, and if we leave this body out of account there is really nothing in the manufacture that can be considered particularly injurious.

With regard to naphtha fumes, there is rather conflicting evidence. As far as the spreading machines are concerned, nothing serious can be urged against the naphtha vapours; where they are too dense the workman who gets too strong a dose rapidly removes himself to a distance, and the danger of fire from concentration of the vapours has led in the majority of cases to efficient ventilation being provided. In the case of large numbers of girls working with rubber solution in a warm and badly-ventilated room in the making up of macintosh garments or pneumatic tyres, there have been several instances of light-headedness or even stupefaction occurring. No doubt in the majority of cases efficient ventilation would have obviated this, but idiosyncrasy in the individual worker is a factor which must not be overlooked. An amount of vapour which will work havoc on one constitution will leave another practically unaffected, and for work of this sort it must not be assumed that all hands are equally suited either in their own

interests or in that of their employers. A judicious weeding out of the constitutionally unfit is desirable in such cases. Dismissal need not necessarily follow if this suggestion were adopted; it would merely mean transference from one department to another. It can hardly be a matter for contention that the more healthy the surroundings of the factory the more chance the workers have of combating any dangers to health which may arise from the incidence of their employment, and therefore it is advisable to take into consideration not only heredity in individuals, but also environment, before generalising upon the healthiness or otherwise of the rubber trade.

CHAPTER II.

PRODUCTION OF RAW INDIA-RUBBER.

All the trees which produce india-rubber of economic importance are found growing in the inter-tropical area comprised within a distance which may be roughly put at 250 miles both north and south of the equator. The climate is, generally speaking, warm and moist, and the rainfall, though varying considerably according to locality, averages about 80 inches a year. Outside this region many plants have been described which contain a milky juice not unlike india-rubber latex in appearance, but despite various attempts which have been made to utilize them, no success has been attained, and they need not be further considered here.

The rubber plants growing in the equatorial belt belong to different botanical orders, which are shown in the annexed table, together with some of the more important species from which the different raw rubbers of commerce are obtained.

Recent botanical research has added largely to the number of species yielding marketable rubber, and has also done a good deal to clear up the confusion which only a few years ago was so apparent on the subject, more especially in regard to African brands. The topic can only be dealt with cursorily in these pages owing to limitation of

space, and those who are wishful of gaining fuller insight must consult the manuals on botany. Much information has also been collected by Seeligmann,[1] Franz Clouth[2] and Chapel,[3] in whose books the existing situation up to a few years ago is ably summarised. Among the alterations in nomenclature, attention may be called to the fact that the

Natural Order.	Genus.	Species.	Locality.
EUPHORBIACEÆ .	*Hevea* . .	*H. Braziliensis* .	Amazon, Orinoco.
	Manihot .	*M. glaziovii* .	Ceara.
	Micranda .	*M. major* . .	Amazon.
ARTOCARPACEÆ .	*Castilloa* .	*C. elastica* .	Central America.
	Ficus . .	*F. elastica* .	Assam, Rangoon, Java.
		F. Vogelii .	Gold Coast.
		F. various .	Soudan, Venezuela.
APOCYNACEÆ .	*Hancornia* .	*H. speciosa* .	Pernambuco, Peru.
	Urceola . .	*U. elastica* .	Borneo.
	Funtumia .	*F. elastica*	
	[*Kicksia* .	*K. Africana*] .	Central Africa. West Africa. Congo region.
	Landolphia .	Large number .	Madagascar. Mozambique.
ASCLEPIADEÆ .	*Callotropis* .	*C. gigantea* .	Assam.

Kicksia elastica of West and Central Africa is now known as the *Funtumia elastica.* Of the trees mentioned in the table, one, the *Ficus elastica,* will be well-known to many as the familiar hot-house plant. It is but rarely to be met with in Europe of the size it attains in East Indian districts, and

[1] "India-rubber Manufacture," by Seeligmann, Torrilhon, and Falconnet.

[2] "India-rubber, Gutta-percha, and Balata."

[3] "Le Caoutchouc et la Gutta-percha."

FIG. 2.—TAPPING LANDOLPHIA VINES IN THE CONGO REGION.

it is hardly necessary to say that, as found in England, it is ornamental rather than useful.

India-rubber trees show great variations in form and size. While the Hevea of the Amazon swamps often attains a height of 120 feet and the Hancornia of 50 feet, the bulk of the Landolphias of West Africa are merely of the creeper or *liane* kind, depending for their support upon other trees of the forest. The greatest insignificance, however, is found in the shrubs from which the root rubber of the Congo State is obtained. These plants have no climbing powers, merely growing from 1 to 2 feet high above the sand. It was with these plants, of which the *Carpodinus lanceolatus* and the Clitandra species may be mentioned, that the somewhat sensational paragraphs which went the round of the daily papers two or three years ago were concerned. Wonderful visions were conjured up of the new source of wealth that had been discovered, though, as a matter of fact, the discovery by the papers was somewhat belated, rubber from this source having been exported from the Congo regions for many years in greater or less quantities. This rubber is obtained, it should be mentioned, from the rhizomes or underground stems.

Tapping the Trees.—The latex or india-rubber milk must not be confused with the regular sap of the tree. Scientists are not yet agreed as to the particular function played by this peculiar secretive body, but it seems to have been satisfactorily proved that, although necessary to the life of the plant up to a certain age, after that time it is no longer so. It will be sufficient to state that after the tree has attained to a certain growth it can be tapped without injury at intervals of time. Generally speaking, young

trees should be six or seven years old before they are tapped, and an interval of a year should elapse between a series of tappings.[1] There can be little doubt that premature tapping injures the trees, and gives, moreover, an inferior product to that extracted from old trees. The

FIG. 3.—HEVEA BRAZILIENSIS.

exact life of a rubber tree is probably not known, but it is within the knowledge of old South American collectors that Para trees have been yielding rubber for at least fifty years.

[1] The latest idea amongst rubber planters is that after the tree has grown old enough to bear tapping, it can be tapped at very frequent intervals with advantage to the yield of latex, provided the tree is not at any time bled to excess.

The rubber latex is secreted in the intercellular veins which are found in the interior of the bark, and though in close proximity to the sap veins, they are quite distinct from them. For further details of scientific interest botanical works must be consulted. Of especial importance are Morellet's contributions to the subject.

There are two methods followed in obtaining the rubber latex, the first or rational one being by making incisions in the bark and collecting the fluid as it exudes, and the second or barbarous method that of cutting down the tree. In the first case, the collector, though desirous of getting as much rubber as he can, works with an eye to the future, while the advantage of the moment is all that enters into the consideration of the rubber gatherer in the second case. In order that full justice shall be done, it ought to be said that all the rubber-producing trees do not lend themselves equally to the tapping process, nor are the conditions of labour identical, for instance, in West Africa and the Amazon region. All the same, it will be generally conceded that the destruction of trees has in the past been carried to a quite unnecessary extent, and that a course of procedure, which is on the face of it irrational, calls, at any rate, for careful consideration, if not for universal condemnation. Human nature being what it is the world over, it is perhaps too much to expect that the untutored collector in little-explored districts will take much thought for the morrow if he himself has little chance of deriving benefit from the result of his forethought. "It is all very well," we can imagine him saying, "for companies who own their own collecting areas to safeguard the interests of the future; their position is such that they can afford to bide their

time." It is pretty clear, therefore, that the native collector, unless under Government supervision, will continue to cut down rather than tap the trees. The reason given for felling the caucho trees in Peru is that the latex will not flow from the upright trunk, also that the tree occurs in such superabundance that any failure of supply is to be considered an exceedingly remote eventuality. This may or may not be the case as regards the latter contention, but if the former statement is not exaggerated it certainly seems to be a matter calling for the attention of experts. There is no doubt that the caucho tree has been exhausted in many districts for the time being, the attention of the collectors being now transferred to what is known as Jebe rubber, a product of the *Hevea guayanensis*, until a new generation of caucho trees arrive at maturity.

The actual process of tapping the Para rubber tree has been so often described, and in considerable detail, that one hesitates to occupy space with matter which is presumably pretty well known. In order, however, to ensure completeness in the treatment of the subject, a condensed account is appended.

The work is carried out by "seringueros," natives who are acclimatised to the miasmatic swamps in which the bulk of the work is carried on. Their number is nowadays largely augmented by learners, who engage themselves during the collecting season to work for the rubber merchants in Para and Manaos, by whom they are supplied with the necessary equipment. Good native labour is by no means superabundant, this being due not only to lack of population, but also to the claims of coffee planters for labour. Moreover, the mortality among even the acclimatised collectors is sufficiently alarming to act as a deterrent to recruits when

labour under more hygienic conditions can be obtained. However, to follow the collectors to their work. On arrival at a suitable tree, they proceed to make incisions in the bark with a small axe, called the "machado," which does not damage the tree, as the instruments formerly employed used to do. The incisions take various forms, sometimes being merely vertical cuts; at other times they take a V-shape, or they may be in curves. Under each of the cuts the collector fixes a small tin cup by means of moist clay, and in this cup the latex slowly collects. Those who have travelled through the Landes from Bordeaux to the Spanish frontier, or on the line from Burgos to Madrid, will no doubt have seen the collecting of turpentine from the sea-pine by means of tin cups affixed to the stems of the trees, the effect in a general way being similar to that seen in the case of Para rubber.

Although the rubber may be collected at any time of the year, the best yield is obtained from the beginning of September to the beginning of February, and the work is usually carried out at this season, which is the period of greatest rainfall. On an average half a pound of rubber is obtained from each tree, not at all a large amount when we compare the yield which is being obtained from cultivated sources. It is probable that the future will see developments in the methods of tapping the trees adopted in South America on the lines which careful study on the Ceylon plantations has shown to be advantageous. At the same time we must remember that the Ceylon planters are only feeling their way, while the Brazilian collector has the experience of his forefathers to guide his actions.

Having obtained a quantity of the rubber latex, the collector proceeds to coagulate it in the following manner :—

In a rudely-constructed oven, called the "fumeiro," having a cone-shaped top, a fire of faggots is made and kept going by

FIG. 4.—SMOKING PARA RUBBER WITH PALM NUTS BY THE PADDLE METHOD.

the addition of palm nuts (*Attalea excelsa*). When a sufficient amount of smoke is being evolved the collector takes a sort

of wooden paddle[1] 4 or 5 feet long, dips it in the latex, and turns it over in the smoke, when the water evaporates, leaving a thin layer of india-rubber. This process is continually repeated until a " biscuit " of ten or eleven pounds weight is formed, and this, after being removed from the paddle by a knife cut, is ready for transport to the trading centres. It is understood that the use of the particular nuts mentioned above is almost confined to the lower Amazon, wood alone being used in the upper regions. Whether these nuts have any very special properties beyond what are to be found in the ordinary timber of the forest does not seem to have been definitely proved, and at any rate the difference, if any, between the products of the nut and the wood smoking is so small that it need not be considered here. The main point is that this smoking process, which is confined to South America, yields the best rubber in the world. This is due, no doubt, to the interaction of several causes, of which the original strength of the rubber latex is a prominent one. There can also be little doubt that the smoking has a beneficial action in arresting any tendency to fermentation on the part of the albuminous matter present. Wood smoke, of course, contains antiseptic matters which may be lumped under the title creosote, a body which is well known as a preservative agent. The amount of moisture in wood and also the large percentage of oxygen contained is conducive to the formation of bodies like creosote and acetic acid, and it seems quite sufficient to ascribe the antiseptic properties of the smoke to these bodies without suggesting, as Clouth does, that the

[1] The form of this implement so long in use has recently undergone a change.

beneficial action may be largely due to free carbon. To judge from the phenomena of charcoal burning as carried out in forest regions, the production of free carbon in the smoke we are considering seems very doubtful, or at any rate, if it is produced the quantity would appear to be so small that its beneficial action must be largely exceeded by that of the creosote, which gives to the Para rubber its well-known and characteristic smell. The proneness of the rubber latex to spontaneous coagulation is counteracted by the addition of a small quantity of ammonia when it has to be carried any distance from the trees to the place of treatment.

With regard to the composition of the latex, analyses have been made, showing about 32 per cent. of rubber to be obtainable from it. The following figures were obtained by the author in 1890 from rubber latex sent from Para in bottles, having previously been mixed with some ammonia:—

Product of the Hevea Braziliensis Para.

	Per cent.
India-rubber	31·9
Resins	1·5
Albumen	0·5
Water and salts	66·1
	100·0

According to Clouth, the latex of the *Heveas* and the *Micrandas* contains:—

	Per cent.
Caoutchouc	32
Organic matters (of decomposing properties)	12
Water	56
	100

with traces of resin. This seems a large proportion of albuminous matters, which were quite small in amount in the above sample. Compared with the amount of work which has been done in raw rubbers of all kinds, it is somewhat surprising that so few analyses of the latex have been published. The difficulty of getting the liquid to Europe in an unaltered condition may well account for this in the past, but nowadays, when rubber is being cultivated in the East at no great distance from chemical laboratories this difficulty has lost its imposing dimensions. That the Para latex is of very uniform composition is seen by comparing the figures given above with an analysis made by Faraday many years ago, the oldest analysis on record. These are his figures :—

	Per cent.
Caoutchouc	31·70
Albumen	1·90
Other nitrogenous and saline matters	10·03
Water	56·37
	100·00

The second quality of Para rubber, known as entrefine, consists in part of remnants from the cuts in the trees and also of what has coagulated in the cups and in part of smoked rubber, it being customary to dip the pieces of the former into fresh latex and then subject the whole to the smoking process. Though free from dirt, this rubber is naturally, owing to its composite nature, not of the same high quality as that which has been carefully smoked throughout. Various other scraps of the rubber, including a good deal which has fallen on the ground and got mixed

with impurities, are made into blocks without going through the smoking process, and are sold as "Sernamby" in South America and "Negroheads" in the European and United States markets.

The methods of production elsewhere than in the Amazon

FIG. 5.—SMOKING PARA RUBBER WITH PALM NUTS BY THE METHOD WHICH HAS RECENTLY SUPERSEDED THE PADDLE TO A GREAT EXTENT.

district prove that nowhere are the operations carried out with such care and regularity. Various methods of tapping are in use where the trees are not cut down, and coagulation is brought about in a multiplicity of ways, many of which could easily be improved. A Mexican process consists in passing the tapped latex through a sieve into an iron vessel in which it is heated until separation of the rubber on the

surface takes place. The defect of this process is that the heating is not sufficient to prevent subsequent fermentation. This method is also said to be employed in Assam. In West and Central Africa a common method is for the collectors to smear the latex over their bodies and to peel off the rubber when the water has evaporated. In other districts, especially in the case of the sluggish latex of the Ceara trees, coagulation takes place on the trunk of the tree by natural heat. The solar rays are also the coagulating medium employed in the case of some of the African rubbers, the latex being allowed to flow from the tree on to the ground, a careless proceeding which cannot be commended. Sometimes, also, the latex is mixed with water in variable proportions according to the custom prevailing in the several districts where the system is in operation; after a time the rubber separates out and rises to the surface. With regard to the coagulation processes used in the Congo region much interesting information has been obtained by Gustave van der Kerckhove, and an article written by him in the *India-rubber World* for October, 1904, has been drawn upon in the following remarks. At least six or seven different methods of coagulation are used by natives in the Congo Free State, and as a rule they show so much acumen in choosing the most suitable process for a particular rubber that the advent of civilization has done little but check adulteration. As the Kassai rubber will be referred to later as the best product of the Congo State, it will be of interest to refer to its preparation. In some cases the method, just mentioned as common in Africa, of smearing the latex over the body and allowing it to dry is followed, while in other cases, instead of using the body, the rubber is allowed to

coagulate as it exudes from the cuts in the vines and is then wound round the finger or on small sticks. What is known in the market as prime red Kassai is prepared by the latter method, while the prime black Kassai is the product of a boiling and smoking process, the natives apparently having discovered for themselves the antiseptic properties of smoke without any assistance from those who would be familiar with South American procedure. Another interesting method of coagulation now largely adopted is the addition of an acid sap called "Bosanga," obtained from a tree known as the *Costus Lucanusianus.* On stirring up a small percentage of this juice with the latex coagulation immediately takes place, the resulting mass being shaped into balls and left to dry in the shade or stored in a bungalow. A noteworthy fact about this Bosanga juice is that it only coagulates the latex from vines, that from trees or from the sources of root rubber being unaffected by it. In extracting the root rubber the natives of the Kwango district and around Stanley Pool, where the particular species known as the *Landolphia Thollonii* is so plentiful, tear up the roots and, having cut them into small pieces, expose them to the sun and afterwards put them into water. The whole is then beaten with sticks to separate the bark. After being dried, the rubber is shaped into sheets half an inch thick, and afterwards cut up into little squares which come into commerce under the name of "thimbles." A large number of processes depend upon chemicals as their active agent for coagulation, alum, salt, sulphuric acid, citric acid and acetic acid being well known in this connection, while in a Peruvian process for treating the Hancornia, soapy water is the agent employed.

An interesting coagulation process carried out in Gambia and on the Ivory Coast is a combination of heat with chemical treatment. The collector makes slight cuts in the stem of the creepers and puts some salt water on them. As the latex oozes out it is partially coagulated by the salt with which it comes in contact, and in this state it is picked off the cut by the collector, who rolls it into a ball with his hands; owing to the rapidity of the coagulation with the salt, the latex is stiff enough to be drawn into threads, and long lengths of such thread are gradually wound up into a ball. They cannot be unwound again, as they unite into one mass. Rubber balls prepared in this way are known in the English market as "niggers," and the adjective "niggery" is often applied to them as a matter of convenience in the rubber works, without leave having been obtained from any authorities on the English language. To revert, however, for a moment to these balls, they are often as much as 2 lbs. in weight, and indeed have been known to weigh 4½ lbs. In making balls of this size, the collector lies down on his back and continues rolling up the rubber while the ball is supported on his body.

The alum method, known also, from the name of its introducer, as the Strauss method, has been unfavourably reported upon, as the chemical has a deteriorating effect upon the rubber. Indeed, much the same can be said of a good many of the chemical precipitation processes, which owe their origin to a desire to get the necessary work done in as expeditious a manner as possible by any available means. The more these methods come under the ken of the rubber expert the louder are their

obvious imperfections likely to be proclaimed, and the nearer shall we approach to the period when this class of work will proceed generally on lines dictated by science.

Briefly summarised, the points which call for special attention, leaving out of account the wasteful destruction of trees by felling, are :—

1. More careful tapping so that other juices in the trees shall not be allowed to mix with the rubber latex.

2. The injudicious mixing of juices of other trees with the rubber latex for the purpose of adding to the bulk.

3. The removal or sterilization of the fermentible albuminous matter present in greater or less quantity in all rubber latices.

All three points are generally recognised as of importance, and the two first may be dismissed as outside the pale of controversy. With regard to the albuminous matters, however, Weber has asserted that their presence in small quantities in washed and dried rubber cannot be looked upon as an incentive to decay, because the albumen is now in the insoluble condition. Whether this be the fact or not, there yet remain notable reasons why albuminous matters should be eliminated as far as possible from the raw rubber in the course of coagulation. Apart from the action which their fermentation in the course of transit and during storage exerts upon the rubber itself, there is the nuisance caused by the smell they give, a nuisance which has given rise to legal proceedings in connection both with the broker's store-rooms and the rubber factories. The above statement of Weber's must not be read as if he thought the

presence of albuminous matters in the raw rubber of no importance, as the proposals he made with regard to the use of formaldehyde and other antiseptics during coagulation point in the contrary direction.

A few analytical figures relating to African rubber are given below.

The first analysis refers to some samples of rubber latex, which the author received from the Colonial Office sixteen years ago, at the very commencement of the Lagos rubber industry, and they are of special interest when we compare the improvement as regards resinous matters shown in succeeding years. The five samples referred to different varieties of the *Ficus Vogelii.* Nothing had been mixed with the latex to retard coagulation, but this had only taken place in three out of fifteen bottles sent. The bottles were under considerable pressure from carbonic acid, the rubber latex having a strongly acid reaction. It contained, besides resins, small quantities of tannin glucose and albumen.

RUBBER LATEX, LAGOS COAST.

Sample.	Rubber, per cent.	Resin, per cent. on the Dried Rubber.	Yield of Rubber per Gallon of Milk.
			lbs. ozs.
No. 1 . .	30·0	31·5	2 13½
No. 2 . .	28·5	32·1	2 11
No. 3 . .	24·5	32·0	2 7¾
No. 4 . .	24·0	33·0	2 5
No. 5 . .	21·0	31·0	2 0¾

It was explained that the samples were gathered at the wrong time of the year, and would consequently be under strength.

The raw rubbers known to commerce can be roughly

classified, with regard to their origin, into four main divisions :—

1. American { South American. / Central American. }
2. African { West and Central African. / East African and Madagascar. }
3. Asiatic.
4. Australasian.

The actual designation under which the various sorts come on the market is derived in many cases from the export station; in other cases from the actual localities whence they are gathered. Again, they may be known simply from their physical state: thus we have such names as Gold Coast "thimbles," Mozambique "sausage," and "biscuits," "balls," "tongues," "flake," etc. Altogether, the nomenclature is of a rough and ready kind, and, moreover, the last twenty or thirty years have witnessed several changes of names, especially in West African sorts. New sorts also are continually coming into the market, while those which were once well known to the older manufacturers have from one cause or another ceased to have any commercial importance. Where such changes occur, it will be recognised that it is of little value to give details which in a short period may be out of date, that is where an exhaustive summary is aimed at. Moreover, a detailed list of the rubbers of commerce would probably be of little attraction to that class for whom this work is more especially written. It is proposed, therefore, to limit the information on this head to a short review of the more important brands of rubber which are now coming with regularity upon the

market. Those who require further detail on this and other points relating to the natural history of india-rubber are recommended to refer to the English translation of Franz Clouth's book on "Rubber, Gutta-percha, and Balata," the author having, with the assistance of Leon Brasse's investigations, put into a concentrated form a large amount of botanical matter. Pearson's book may also be consulted for details regarding the occurrence of the various brands of rubber.

Names and Principal Characteristics of the Chief Crude Rubbers of Commerce.

I. *South America.*

1. *Para.*—Fine Para like the other Para sorts to be mentioned, is derived from various species of *Hevea,* the bulk of the supply coming from *Hevea Braziliensis.* It comes in the form of loaves or biscuits of several pounds' weight, which are of a cream colour internally, though the exterior is usually a dark brown or black. The biscuits are built up in concentric layers of thin sheets, a result of the curing process. The characteristic smell of wood creosote is always present.

Fine Para rubber, which is the best and forms the standard by which all other sorts are valued, varies slightly in its properties and price according as it is "Up-river hard cure" or "Island soft cure." The former comes mostly from the wooded regions far up the Amazon valley, being shipped from Manaos, while the latter is chiefly obtained from the islands near the mouth of the river. The two brands are very similar in appearance, though the

"Up-river" rubber generally comes in larger loaves or biscuits than the "Island," weighing, indeed, as much as 100 lbs. each biscuit.

A second grade is known as "Entrefine." It has a rather lower value owing to its having been imperfectly smoked.

Then there is what is known as "virgin" rubber, which is unsmoked fine rubber, coming in the form of rectangular slabs of a pale yellowish white colour. Its source of origin is mainly Matto-Grosso.

Fourthly, we have "Sernamby" or "Negroheads," already referred to, which consists of irregular lumps of fine rubber mixed with a good deal of bark, and often earthy matter. This rubber is the scrap which is obtained from the trees and the ground where it has escaped collection in the cups; there are also the residues which have coagulated in the cups. From these sources the heterogeneous rubber known as "Negrohead" is derived. Though nominally the same rubber as the fine Para, it has suffered by the irregularities in its coagulations, and after allowing for its extraneous impurities it always has a lower value than the other Para sorts.

The fifth and last rubber to be mentioned under the head of Para is "Cameta," which has only in the last ten years become of importance on the European markets. The name is derived from the part on the Tocantins river, south of Para. It is unsmoked and appears to vary a good deal in the amount of its impurities, which are of an albuminoid rather than fibrous nature. It comes in the form of balls, cups, and slabs; these are usually very moist and clayey, leading to a very high loss in washing; for the rest, the rubber is hard and of good colour and texture.

2. *Peruvian Ball and Slab.*—Although Peru yields a good

deal of fine Para rubber, its more particular product is a second-rate brand known as "Caucho," more closely approximating in its qualities to Central than South American rubbers. A few years ago it was comparatively little known on the European markets, being chiefly used in the United States. It is not cured by smoking but is coagulated by some alkaline solution, or by the addition of soap. The tree has recently been identified by Uhl as a *Castilloa*, and has been named *Castilloa Ulei* by Warburg. Of late this rubber has been extensively used in Great Britain as a medium quality. Coming in large quantities and of fairly regular quality, it suits the trade better than other brands which only arrive spasmodically.

3. *Bolivian*, in the forms of "fine," "entrafine" and "Negroheads," is practically the same rubber as Para. Owing to its careful preparation and greater dryness, it commands the highest price among raw rubbers.

4. *Pernambuco* or *Mangabeira* rubber is derived from a Hancornia species and comes in wet rectangular slabs, often containing an excess of impurities. Coagulation is usually effected by alum. It arrives only in limited quantities and is evidently one of those brands which would benefit under more scientific and careful collection and preparation. Maranham is another variety derived from the State of that name. These rubbers are rather inelastic and usually arrive in a very wet state.

What is known as Pernambuco and Assare scrap much resembles Ceara scrap, being collected in the same manner. It is even more sandy and barky and its stickiness renders it difficult to clean thoroughly. It shows a very variable loss in washing.

5. *Bahia* rubber comes from the Brazilian province of Bahia. The tree is one of the Hancornia species, and the rubber, which comes in lumps or slabs, is found to be of variable quality, some of it being almost as strong as Para.

6. *Columbian*, also known as "Cartagena," is derived from

FIG. 6.—CASTILLOA ELASTICA.

trees the identity of which is not well established. It is possibly, in its many forms of sheet and strip, a product both of *Hevea* trees and of the *Castilloa elastica*. The production seems to have decreased of late years. The large balls or slabs, in which form it is also exported, are black on the outside and a dark grey internally. Coagulation is

carried out by various methods, of which the use of the bindweed milk may be mentioned, though this is said by some authorities to produce an inferior rubber to what can be obtained by other methods.

The same remarks as to improvement in the method of collection apply here as to the Pernambuco rubber.

7. *Guayaquil* rubber, which comes from Ecuador, has much the same origin and characteristics as the preceding. The best quality has a whitish cut, while inferior sorts are extremely porous and contain a good deal of decomposing albuminous matters.

8. *Ceara* rubber is obtained from the *Manihot glaziovii*, in the province of Ceara, Brazil. It is a very dry tough rubber, coming in the form of a mass of shreds or ribbons. It is allowed to coagulate on the tree as it exudes and always contains bark and dirt. Owing to its nature it is not in general demand, there being considerable difficulty in freeing it entirely from its impurities. The Ceara "Negrohead" is more sought after.

Central America.

The indigenous tree in Central America and Mexico is the *Castilloa elastica*, and the rubbers to be referred to are all derived from it or from allied species. Their variations as regards quality and market price must be attributed to the greater or less care with which they are gathered and prepared. In this summary it has been thought advisable to adhere to geographical limits and not to include the produce of the northern part of South America proper among "Central" brands. In trade circles, however, it has become customary to refer to all rubbers obtained north of the Amazon valley

up to Mexico as "Centrals," and there is good reason for this on account of practically all of them being yielded by the same species of tree and being of much the same value in the manufacture. The point is not, of course, an important one, and needs no further reference.

The usual method of coagulating the latex is with the juice of the bindweed, though procedure in the different countries is by no means uniform. According to Pearson, the consumption of Central American rubbers in the United States has much decreased in late years and only small lots find their way to Europe.

Another trade name for Central American rubber is "West Indian," though none of it actually comes from the islands.

1. *Nicaragua* rubber comes in scrap and sheets of an almost black colour. Greytown is the shipping port both for this rubber and also for some of that derived from neighbouring States.

The quality of this rubber is often very high and it comes to the market in a drier state than many varieties of "Centrals." Indeed, it is considered by many to rank directly after Para.

2. *Panama* rubber may be considered together with that from Costa Rica and Honduras; what is shipped at Panama being as a rule mixed up lots collected from different States, not only in Central America but also in the north of South America. All these are the reputed product of the Castilloa, though there are variations in the methods of coagulation practised. Certain species of Hevea trees are also reported as being tapped along with the Castilloas in this area.

3. *Guatemala* sheet comes from the State of that name,

and can always be recognised by the strong smelling characteristic viscous liquid it contains. It is usually coagulated with bindweed juice and there is little doubt that the quality could be much improved by more careful preparation.

4. *Mexican* rubber, which is produced in dark strips, has shown a decreased output in recent years, and is now of little importance in the European markets. As, however, the numerous plantations have now begun to yield, there is every probability of the country regaining its original position as a producer. The *Castilloa elastica* is the common tree, and coagulation is usually effected by boiling the latex with the addition of water. The small balls of this rubber are of much superior quality to the more common form of large slabs.

II.—*African Brands.*

As already mentioned, large quantities of rubber come from Africa, and despite a noticeable diminution from certain districts the total output shows a continual increase. In the following account the principal kinds, which are more or less in regular use in British rubber factories, are referred to, though not necessarily in order of merit.

1. *Gambia* is a very useful rubber for general purposes. It comes mostly in mottled, stringy, wet balls, and like most other African sorts, it is usually graded into four standards. Though a fairly hard rubber as a rule, it is often mixed with an inferior latex.

2. *Sierra Leone or Massai* rubbers are of somewhat variable name and origin. They come in the form known as "niggers," which have been previously described. These

are either red or white, the former being the most sought after. They are often mixed with Conakry, and the better qualities of Soudan "niggers," etc. The selected, or first grade, is a very useful hard rubber, fairly clean, and it is often bought months ahead by some manufacturers. The other grades very often contain heated centres, besides being more dirty. These rubbers also come in the form of twists, which though a sound and useful rubber, are not so clean or in such good condition as the red "niggers."

3. *Gold Coast.* This rubber is known chiefly in the form of lumps or slabs, and in small quantities also as "niggers." The Gold Coast lumps are usually very wet, and when cut show a yellowish-white colour. The interior of the lumps are more or less spongy, and nearly always full of water and uncoagulated latex, which naturally means a high loss on washing. They are made up into two standards, Coast selected or Liverpool selected as firsts, the softer and more resinous lumps being classified as seconds. The rubber is fairly clean, and always in good demand, though its smell derived from fermenting nitrogenous matters makes it objectionable for some purposes. The outsides of the lumps are quite black and often very dirty, and some manufacturers make two grades by cutting off the outsides, and using them for one purpose and the insides for another.

4. *Benin lump* is very similar to that last described, but usually firmer, of a closer grain, and not so spongy. It has a yellow or bluish tint when cut, the colour being usually deeper than in the Gold Coast lump. Like the latter, it is divided into two grades for sale.

5. *Lagos lump.*—The foregoing remarks apply to this, but it is perhaps not quite so uniform in quality as the Benin. The best selected, however, is one of the best lump rubbers, being usually firmer and less resinous than the Gold Coast. It can be distinguished from other brands by its peculiar odour.

6. *Liberian.*—This is a lump rubber of rather variable composition, and is not in great favour owing to its most objectionable smell. On being cut open it shows variable tints, from yellow to blue, the latter being generally considered the best quality. When the newly floated Liberian Rubber Company has got thoroughly to work, no doubt we shall see this rubber arrive in a condition which will ensure it a better reception than is at present the case.

7. *Niger.*—This usually comes in bags in a solid mass, which would be better described as slab than under its usual name "niggers." The colour varies from grey to red, sometimes, indeed, being almost black, as a result of over-heating. A large proportion of red bark and dirt is also present, and this means a good deal of trouble in washing. A drawback to this rubber is that the colouring matter from the red bark is apt to remain in the washed rubber, and this if used for a white compound spoils the shade. Some of this rubber is soft and resinous, and comes on the market as Niger gutta or paste. This rubber would be much more useful if more care were taken in its collection and preparation, and in packing for transport.

8. *Mozambique*, a very strong and elastic rubber, comes chiefly in the form of stringy balls of various size, and also as sausages, that is, strings of rubber wound round pieces of stick, which entail a good deal of trouble in their extraction;

also it is found in the form of smooth cakes, to which the descriptive name of "liver" has been applied. All classes of Mozambique rubber find a ready sale.

9. *Madagascar*, which principally comes as irregular cakes, is generally referred to as pinky Madagascar, owing to its characteristic colour. It is a good, clean and useful rubber. The Majunga balls are not so clean, and very often contain some of the pinky rubber found in these centres. Another grade, known as East and West Coast "niggers," is usually very dirty, and this detracts a good deal from what would otherwise be a very strong and elastic rubber.

10. *Congo sorts.*—The various grades of rubber coming from the Congo Free State are in great demand, as they bear the impress of a more careful preparation than is the case with the bulk of the West African sorts. They come chiefly in the form of small balls and strips, and are known under many distinctive names, according to their gathering grounds. Among the Upper Congo sorts best known in England are Aruwimi, in the form of large balls, often heated in the interior; Equateur, small balls, usually dry and clean; Lopori, coming in ball, strip and sausage of very varying quality; Uelle, in strips and cakes of rather low quality; Mongalla, which arrives in ball and strip of good quality; and lastly, Wamba thimbles, also of good quality.

As the loss of these rubbers in washing varies to such a great extent in different lots, it has not been thought desirable to give any figures in the table of losses in washing to be found further on. With regard to the variation in quality often found in particular brands, there seems little doubt that fermentation setting in in the hold of the steamer is frequently the cause, and more careful conditions of

transit might be adopted with advantage. Antwerp is the principal market for these rubbers, and they are not sold by auction, as in England, but by tenders received on the strength of sample lots which have been sent to prospective purchasers.

III.—*Asiatic Brands.*

The *Ficus elastica* is the principal rubber-producing tree of Eastern Asia, though recent botanical research has caused the identification of distinct though allied species. The rubber is not of the same high quality as the Para, and it is noteworthy that in the plantations now springing up in such profusion in the East general attention is being restricted to the cultivation of the acclimatised Hevea trees to the almost total neglect of the indigenous species. Compared with the imports from South America and Africa the amount of Asiatic rubber which comes to England is quite insignificant. These rubbers, particularly in the lower grades, are somewhat inelastic; they contain a large quantity of fibrous and earthy matter, and show a tendency to heat, *i.e.*, become sticky very quickly.

1. *Assam* rubber is prepared in the form of balls composed of the strings of rubber which have been allowed to coagulate on the trees. There are four grades of it, differing a good deal in their quality. This rubber was first exported to London in 1828, and, as we shall see in another chapter, it was the decreased yield in this part of the world which gave rise to the idea of rubber planting. This rubber contains a very hard resin as well as a soft one, their respective melting points being 82° C. and 12° C.

2. *Rangoon* rubber comes from Burma, and much

resembles the Assam. Its output in recent years has increased, while the Assam supply has diminished.

3. *Penang* comes principally from the island of that name, and also from the Sunda islands, in the form of balls, slabs, and " sausages " of a reddish colour. It varies very much in

FIG. 7.—FICUS ELASTICA.

quality, and is generally inferior both as regards impurities and elasticity to the Assam and Rangoon rubbers.

4. *Java* rubber differs but slightly from Assam, though it can generally be distinguished by its darker tint and occasional red streaks. Admixture with gutta-percha is not unknown.

5. *Borneo* rubber is not in much demand on account of the amount of water and dirt it usually contains. In

general appearance it comes in slabs of a whitish colour, turning pink when stored for any length of time. It contains, or used to do so, a good deal of a curious volatile sugary substance, first extracted by Girard in 1871, and called by him "bornesite." A very similar body had previously been found by him in the Gaboon rubber of West Africa.

Whether this is a natural constituent of the latex or is an adulterant added by the native collectors does not seem to have been satisfactorily cleared up. Borneo rubber usually arrives very wet, and is apt to contain many small pieces of wood, which are not detected until the balls or slabs are cut up small. The lower qualities are also very gritty and dirty. This rubber is always characterised by its white colour and great humidity. It is the product of the *Urceola elastica*, a tree which has been known to send out lianes 180 metres long, according to Chapel.

IV.—*Australasian.*

Of even less importance commercially than the wild Asiatic supply is that which comes from Australasia from certain species of Ficus :—

1. *New Guinea* balls come in the form of strings of small balls, sometimes of superior quality, but showing great variations in this respect.

2. *New Caledonia* rubber, which is quite a recent introduction to the European market, besides coming in balls is also found in the biscuit form like Sara.

3. *Noumea* is another rubber similar in almost every way to the last named.

Pseudo Rubbers.

The raw rubbers which have been mentioned, as well as several more which have not been specifically referred to, by no means comprise all the crude material which the tropical forest supplies to the rubber trade. There are several substances which, for want of a better term, are known as "pseudo rubbers," which come into the market in greater or less quantities. Some of them resemble rubber, some gutta-percha, while others are practically all resin. There is little doubt that in parts of Africa the natives mix resinous latices of this class with the rubber so as to increase the bulk. Looking at the various pseudo rubbers which have appeared in the market so far, the chief point about them is their slight value compared with sound rubber. They are referred to as low grade rubbers, but as they consist for the most part of resins, it would be more correct to term them superior resins, superior that is for rubber-manufacturing purposes. One of these bodies, known variously as potato rubber, almeidina or euphorbia gum, was introduced into England more than twenty years ago by a London firm of produce brokers. On the strength of its supposed properties some rubber manufacturers bought a good deal of it at 6*d*. per lb. (Fine Para being then 2*s*. 6*d*. per lb.), but had cause to repent the transaction. The potato rubber, so called from the form in which it is imported, is obtained from the tuber-like roots of a tree or shrub which has been found principally in Portuguese West Africa, the Cameroons and the Solomon Islands. Its composition, roughly speaking, is 90 resin and 10 rubber. It will be seen, then, that its value is very small, and what

was bought on its introduction at 6*d.* per lb. was afterwards valued at 2*d.* In recent years it has not increased in favour, as it can only be used in admixture with rubber for certain low quality goods, and even then, in the author's opinion, it could be profitably dispensed with in favour of other material. When put into boiling water potato rubber can be drawn out into threads. A rather curious point about the substance is its supposed poisonous properties, men who have worked it on the hot rollers complaining generally of the effect of a pungent vapour it gives off. Whether this effect is due merely to an irritant or to some specific poison does not seem to have yet been determined. Another body which has been used in large quantities in recent years is Pontianak, also called Jelutong in the United States. It comes from the town of Pontianak, in Borneo, in white lumps, smelling strongly of petroleum. Its composition in the dry state is 75 to 90 per cent. resins, and 25 to 10 per cent. rubber-like substance. The increased demand indicates that it is of more value than potato rubber, though it has hardly any claim to be considered as a raw rubber. It has been used to some extent in England as a binding material in the reclaimed rubber manufacture, and, it is said, is now being used for proofing purposes. In America it has had a wider application in connection with the rubber manufacture.

The removal of the resins by solvents formed the basis of a secret process recently exploited for the treatment of Pontianak, but it is difficult to see how any such project could be financially successful, because not only is the proportion of resin very large, but the purified rubber is only of low quality. With regard to the production of

Pontianak, it is got from the tree known as *Dyera costulata*, by breaking the bark and allowing the resinous exudation to collect in tins. The coagulation, or rather preparation, is effected by mixing it with water and petroleum spirit, a small quantity of a special powder obtained from China being also added. This powder has been shown to consist of fibrous gypsum, and its supposed utility is not apparent. The above materials having been well mixed together the product is rolled into the balls in which it is exported. Although numerous other substances have a legitimate claim for consideration here, there are only two more which seem to have any regular use. These are Chicle gum, obtained from the *Achras sapota*, a common Central American and Mexican tree, and Tuno, which is the coagulated latex of the sterile rubber tree of Nicaragua and Honduras. The latter is said to be used in conjunction with balata in the belting manufacture, while the former, though its principal application is in the chewing-gum business, is reputed to be used in connection with rubber insulation. These last products are very little in evidence on the European rubber market, the United States taking the bulk of the output.

Congo India-rubber.

It is a good many years ago since Stanley prophesied the future greatness of the district known now as the Congo Free State as a source of india-rubber. At the time non-expert writers saw in this announcement the impending fall of Brazil from her high position as the principal source of the world's supply. The fact that the Congo region produces no rubber of anything like the high quality of

that of Brazil was entirely ignored. Before 1890 there was practically no raw rubber market at Antwerp. In that year the rubber changing hands amounted to thirty tons, five years later it rose to five hundred and thirty-one tons, while successive years showed rapid increases to the neighbourhood of six thousand tons in 1900, although it should be mentioned that the Antwerp imports are not by any means confined to rubber from the Congo State. One result of the methods employed is that large areas in readily available districts have been rapidly depleted, a circumstance which is reflected in the diminution shown in the exports to Antwerp in 1902. A word or two may be said on technical points, though much that bears upon these has already had mention in other chapters. The trees belong almost entirely to the Landolphia class, already mentioned as giant creepers, and owing to the density of the forests rubber-bearing parts often have to be cut away at a considerable height where they have climbed towards the light by the support of the other trees. This necessitates a good deal of climbing, adding considerably to the ordinary danger and labour associated with rubber gathering. With regard to the rubber itself a great improvement is noticeable compared with the Landolphia rubber shipped from the Congo region twenty years ago. Not only has the open sophistication with extraneous matter ceased—this was only to be expected in the circumstances—but the coagulation of the rubber latex is being carried out on lines which give a superior product. More attention is now being paid than at first to drying the coagulated rubber out of the direct rays of the sun, a procedure that led to a superficial sticky composition. No doubt also we may look for improvements

in coagulation which will give the manufacturers less reason to complain of "sweated" rubber. This not very appropriate name is given to rubber which on arrival in Europe shows a sticky decomposition in the *interior* of the balls, due no doubt to fermentation of albuminous matters.

FIG. 8.—LANDOLPHIA OWARIENSIS.

That considerable improvement is already shown in West Coast rubbers generally is testified by the keenness of the British in bidding at the Antwerp sales.

Raw Rubber: Some General Considerations.

We may briefly discuss now one or two points of some importance with regard to the collection and exportation of

rubber. It is not surprising that the increase of intelligent supervision has led in some cases, and promises to do so in others, to an improvement in the methods of tapping, coagulation and other processes by which the rubber is prepared for export. Originally all this technical work was left entirely to the native collector, who operated according to his own lights, and it certainly seems more in accord with the fitness of things that a commodity of such a high value should receive skilled supervision in its preparation as well as in its manufacture. Of course the chief difficulty lies in the practical impossibility of exercising supervision over the natives who carry on their work at scattered points in the depths of the forests, and where, moreover, the climatic conditions are apt to prove rapidly fatal to Europeans. It is easier to say what is desirable than to indicate precise methods for accomplishing the ends desired. There is plenty of evidence, however, that those who are concerned with the harvesting of the rubber crop, especially in West Africa, are likely in the future to achieve considerable success as a result of the reforms which have been initiated, and which are being pushed with all the energy that circumstances will allow. The wholesale destruction of trees has in most of the districts been forbidden by law, and where the yield of certain areas has suffered serious diminution owing to the reckless gathering, laws have been passed prohibiting the export for a certain period of time. This was done, for instance, in the case of Lagos rubber. Owing to the great falling off in the export a few years ago, the gathering was prohibited for five years. Lagos rubber, which on its first introduction in 1890 was not highly thought of by the manufacturers, owing to its high content

of resins, was later received with greater favour owing to the improvement shown in its quality.[1] It was not unnatural, then, that the threatened collapse of an industry which was an important source of revenue to the colony in the way of export duties should have been regarded with apprehension by the authorities, and it will be admitted that the somewhat drastic steps taken to insure the future of the industry were conceived in the best interests of all concerned. Experimental work is being actively carried on by botanists at several Government botanical gardens, as well as by private individuals; the work of the Liverpool Institution of Tropical Research should also be mentioned in this connection. A feature of the situation is the great increase of interest in the raw rubber supply which is being evinced by the manufacturers, compared with what obtained twenty years ago. The community of interests needs no emphasis, and those who are working on the botanical side have now little or nothing to complain of with regard to the attitude taken up by the manufacturers respecting their work. Here, without wishing in any way to be didactic, the author feels constrained to pass a word of comment on a certain matter. A tendency is noticeable among the new scientific investigators to show impatience at the caution evinced by manufacturers in buying any new product. The experience gained in years of work in the factory, largely empirical though it may be, enables the manufacturer to lay a safe course, and he knows that any deviation may prove disastrous. It is not surprising, therefore, that the enthusiastic investigator often finds him slow to recognise the importance of a discovery and its predicted

[1] Recently, however, it has again deteriorated.

far-reaching effect upon the trade. The practical man in the rubber factory has often failed to receive justice at the hands of scientific writers, but those who really know the trade, its intricacies and its pitfalls, will be slow to condemn his conservatism. When he is shown half-an-ounce of an inferior rubber transmuted by up-to-date methods into Para, his habitual caution arouses a desire to see a ton of it before giving the discovery the seal of his approval. It may be a perfectly practical process as far as he knows, but he prefers to adopt a negative attitude until he is satisfied on all material points. The period of probation, then, must perforce be somewhat lengthy; but apart from this it may be taken that, the interest of the manufacturers having now been aroused, their support and encouragement will continue to be at the service of those who from one cause or another are endeavouring to utilise to greater economic advantage the natural resources of the rubber forests. The improvements which have been already effected in the preparation of several of the West African brands of rubber will no doubt in the course of time be extended to others. There is no good exporting sand, fibre and water, and the practice of mixing the resinous saps of other trees with the rubber in order to swell the bulk has certainly no justification. Moreover, the over-heating of the rubber, due to exposure to the sun's rays, is a source of damage that could no doubt be largely minimised. At the same time, speaking more particularly of mechanical impurities, it is not at all clear that their removal by the exporter is a matter of expediency. To take a concrete instance, the British manufacturer complains of the amount of sand and fibre which he gets with the Ceara rubber; he says it ought to be exported in a

cleaner state. As a matter of fact, the collectors in Ceara have gone into the case carefully, and find that the difference in the price which they can obtain for the purified rubber does not pay them for the extra labour involved. This, of course, does not answer the whole objection; it remains to be seen whether the rubber cannot be prepared in such a way that sand and bark are not allowed to get intermixed with it. Until a new method of procedure is evolved, the rubber will continue to be shipped in an impure state. Possibly this case has its parallels in West Africa, and before we can expect the rubbers in a cleaner condition it will have to be shown that the necessary work will prove remunerative to the exporters, including in this term the collectors. Turning to another matter, nothing seems to have been advanced in recent years in support of the idea that rubber of an inferior quality would be found equal to Para rubber if its impurities, especially its resins, were removed. The whole subject is a very intricate one, and on the present occasion it is sufficient to state that, while some of the Landolphia rubbers when well prepared are quite equal to second-grade Para sorts, yet, whether on account of some chemical difference in the latex, or from the methods adopted in collection and coagulation, the very best rubber has not yet been obtained from other sources than the Para rubber trees of South America. Some years ago the author extracted the resins from a quantity of first quality African ball rubber and had the latter made into elastic thread under ordinary conditions. The product, however, proved to be decidedly inferior to ordinary Para thread in tensile strength. It is not contended that this experiment proves more than that the removal of resins in

the rubber is useless in order to convert a low grade of rubber into the highest one. It may be shown that the intimate association of the rubber and the resins has permanently damaged the former. Possibly if the resins had never intermingled with the latex, or had been separated from the rubber during coagulation, the latter might have been found to possess better qualities than is ordinarily the case. With few exceptions the attention of planters is being confined to the best quality of rubber; points such as the above will therefore more naturally come under the notice of those who are engaged in exploiting the product of untended nature, or are concerned with the replanting of the indigenous trees in denuded districts.

Apart from various Congo sorts and the very partial introduction of brands from Australasia, there has not been much of novelty—plantation rubber apart—to engage the manufacturers' attention lately in the raw rubber market. Reference may, however, be made to the Maniçoba rubber, about the origin of which some misunderstanding is current. This rubber is not derived from any new source; it is merely the product of the ordinary Ceara rubber tree, *Manihot glaziovii*, grown in Ceara from seed. Of late there has been a disposition among the Cearense to put to use in their own country the knowledge concerning Para rubber which they have acquired when collecting in the Brazilian swamps. An instance of this is seen in the smoked Ceara rubber which is now on the market, and which is known locally as "profumada," to distinguish it from the ordinary unsmoked sort. The Maniçoba rubber is not smoked, and ranks with good second-quality Para sorts. If it were not for the large amount of fine sand which it so often contains, and

which makes it so difficult to thoroughly wash, it could be used for best quality purposes, as it has a high tensile strength.

Guayule rubber is a new product which calls for more than passing notice, as its preparation involves a somewhat new departure. The plant which yields it (*Parthenium argentatum*) is found in abundance on large tracts of waste land in Mexico and Texas. It is a shrub containing rubber in its branches, and several patents have been taken out in America in connection with processes for its economical extraction. The yield of rubber has been variously stated, but according to the *India-rubber World*, which has devoted considerable space to what is being done with *Guayule*, the yield, as gauged from comprehensive experiments, is 8 per cent. of the refined rubber. As tapping is out of the question, the process adopted consists, roughly speaking, of cutting the shrubs into pieces and separating the rubber substance by maceration in water. There are, however, several patent processes of extraction in operation, and the last word has by no means been said as to which is the most satisfactory method of procedure. The International Guayule Rubber Company has been formed to exploit a large acreage of ground in Mexico, and they estimate that their special machines will extract 3,000 tons per year. Unlike the Colorado rabbit-weed rubber, which has so far utterly failed to substantiate its much-vaunted claims, Guayule rubber is already on the market. Large quantities have been used in America, and it is now before the notice of European manufacturers. With regard to its value, it is pretty clear that this was at first overrated, and it is not surprising that it is now being sold at about half the price originally asked

for it. A good-class sample recently analysed in the author's laboratory gave the following figures :—

	Per cent.
Rubber	53·02
Resins	21·82
Water	24·78
Ash	·38
	100·00

Time alone will show whether the extraction process will justify the expectations of those who have embarked in the industry with so much enthusiasm, but it is noteworthy that a factory on a large scale is being started in Germany, where, of course, freight will have to be paid on the raw material.

The Continental Guayule Company, which was recently incorporated under the laws of New Jersey with a large capital, have obtained possession of Lawrence's American patent for the extraction of guayule. Two or three quite distinct processes are involved in these patents. In one of these the shrubs are put through corrugated rollers and extracted with naphtha. The solution obtained is then distilled down to a certain point and alkali is added; this dissolves the resin and causes the rubber to separate out. In another process the guayule is obtained, as already mentioned, by maceration in water, but it is afterwards treated with wood naphtha or alkali in order to extract the resins. From one or other of these processes a guayule rubber, practically free from resin, has recently been put on the market in trial lots, and as long as the raw material lasts no doubt it will remain a regular article of commerce.

It has been stated on page 37 that although the expression West Indian is often used for Central American rubbers no rubber comes actually from the West Indian islands. This is correct for the present, but in all probability the rubber vines which are found in Jamaica will be utilised before long. Samples of the rubber coagulated by exposure to the sun have been examined in England, and the quality is beyond question. According to the Kew authorities, the rubber is yielded by the *Forsteronia floribunda.* It will probably be found that this creeper is common enough in Hayti and San Domingo, though the weak point about the prospective West Indian wild rubber industry seems to be that its life must inevitably be short. In addition to the limited area of the gathering grounds, there is the fact of it being necessary to destroy the vines to get the rubber. Moreover, replanting of indigenous trees is hardly likely to be carried on, because if anything is done in the plantation way attention will assuredly be concentrated on the Para rubber tree, which yields the best return to the investor.

The two principal ports into which the raw rubbers referred to in the previous chapter come are Liverpool and London. Their pre-eminence in this respect, as far as continental supplies are concerned, has suffered a serious diminution during the last ten years owing to the rivalry of Antwerp, Hamburg, Rotterdam, Havre, Marseilles and Bordeaux. The great bulk of the supplies comes to brokers who make a speciality of the business, and it is sold by auction to the rubber merchants. Strange though it may seem to the buyers of other commodities in bulk, such as metallic ores and cellulose, chemical analysis is not used at all in determining the price to be paid. The ordinary procedure is

for the merchants to post small sample lots of the rubber on offer to the manufacturers, who buy on the strength of a superficial examination alone. Sometimes the deal is effected on post samples alone, or the manufacturers may send their trained buyers to inspect the bulk. Undoubtedly crude and open to errors as this procedure may be, it still remains for those who have strenuously advocated chemical analysis as the proper basis on which to found ideas as to value to show how the alteration can be carried out. It will be evident from what has been said as to the nature of the raw rubber, its protean forms, and its varied characteristics, that the taking of a correct sample indicative of the bulk, say, of several tons, must prove an exceedingly difficult undertaking, leaving out of consideration altogether the expense which would be involved. Not only does the rubber arrive in most cases in very small pieces, but the contained impurities are very unevenly distributed. As the suggested alteration of procedure has not so far been seriously considered by the trade, its pros and cons need not receive detailed notice here; it will suffice to say with emphasis that any change will have to be made on very carefully considered lines, and that if discrepancies are to be avoided a close understanding must be arrived at between the chemists employed by both buyer and seller as to the actual details of the methods of testing adopted. Even in such a comparatively simple case as the cellulose boards imported into England from Scandinavia for paper-making purposes, it has been found extremely difficult to arrive at the true percentage of moisture, not because of faulty work on the part of individual analysts, but because the water is unevenly distributed in the mass, thus making the sampling procedure a matter of

the first importance. With regard to fine Para rubber which arrives year by year, of practically uniform composition, there is little or no risk of loss by bad judgment under the prevailing conditions ; it is in the lower grades of rubber, in which the impurities vary to such an extent that the buyer's faculties of discernment come into prominence. Unlike the tea-taster, who receives a large salary for his work of discrimination and retires with his health ruined, the raw rubber expert uses only the senses of sight and smell, and if he is not paid on a princely scale it can be said that his work is not of an unhealthy nature, although there certainly are pleasanter substances to associate with than albuminous rubber which is undergoing fermentation in a badly-ventilated building.

Nowadays the grosser impurities—adulterations would be a more correct term to use in this connection—such as metal, added for weighting purposes, are not met with, and the impurities that have to be ordinarily dealt with consist of sand and woody fibre, together with some albuminous and saccharine matter. Water is, of course, always present in greater or less quantity, and there may also be evidence of the chemicals used in coagulation. These impurities have all to be removed, or as far as possible removed, by the manufacturers before the rubber can be used. The sum total of these impurities is known as the "loss in washing," and the figures for the various brands of rubber are of considerable importance in the economy of the manufacture. It is not surprising that these figures, as obtained in different works, show considerable variation, particularly in the lower grades of rubber. This is the case in those published by Chapel, Pearson, Clouth, and Weber in their respective

books. The differences may be attributed to two main causes, the most prominent one being the probable variation in the raw rubbers, and the other the varying degree of exactitude with which the washing and drying operations were carried out. In the following table, which does not claim to be an exhaustive one, will be found figures, kindly furnished by one of our prominent manufacturing firms, as the mean result of their own experience. It is thought that a table giving the recent results of an English firm will prove of more interest than any reproduction of figures already published, authoritative though they may be.

Another, and the most important, impurity in crude rubber has now to be mentioned. This is the resin, to use the singular number for a group of bodies which are found in the various brands of rubber. Although, of course, their existence was known, nothing definite with regard to them seems to have been published until 1889, when the author read a paper on the subject before the Society of Chemical Industry.[1] In this paper he showed that not only did all the brands of rubber contain resinous bodies largely peculiar to themselves, but that these resins were quite distinct from the oxidation product of vulcanized rubber previously described by Spiller. The further reference to this topic will come more fitly under the head of the chemistry of india-rubber.

The chief point of practical importance about these resinous matters is that, unlike the other impurities, they are not removed from the rubber in the ordinary washing process, and they therefore form a component part of rubber goods.

[1] *Jour. Soc. Chem. Ind.*, 1889.

For the sake of convenience, the percentages of resin in the different rubbers are tabulated next to those referring to the loss in washing, the figures being calculated on the washed and dried rubber, and not on the raw product. It is only in this way that comparative figures of any value

FIG. 9.—CARPODINUS LANCEOLATUS (AFRICAN ROOT RUBBER).

can be obtained, otherwise it is obvious that the stated amount of resins would depend as much on the other impurities present as upon the rubber. Since the publication of the author's original paper considerable attention has been paid to the subject of resins in raw rubber, and numerous estimations have been made. Of those who have

published figures we have C. O. Weber,[1] Clouth,[2] and L. M. Bourne.[3] As the figures are obtainable by a simple laboratory operation necessitating no particular skill, and as such determination now forms part of the regular routine in the more important factories, it is not proposed to quote any individual authority. The figures given in the table are derived from other sources as well as from the authors' note-books, and are given as being most generally true for the particular rubber brands concerned :—

	Loss on Washing.	Resin in Washed Rubber.
	Per cent.	Per cent.
American—		
Para	16—20	2·5—3·5
Ceylon Para	Best 1—4 Inferior crêpe and scrap lose a good deal more.	1·8—2·5
Straits ,,		1·5
Virgin	18—22	2·5
Negroheads	40—50	3—4
Ceara Scrap	25—35	3—4
Maniçoba	20—50	3—4
Peruvian Ball	25—30	4—5
Cameta	40—50	2—3
Mangabeira	30—40	5—6
African—		
Red Sierra Leone Niggers	12—25	7—9
Lagos Lump	40—45	18—20
Upper Congo	Various	
Red Kassai	6—8	4—5
Benguela	20—30	4—5
Mozambique Ball	12—25	6—7
,, Sausage	12—25	6—7
Madagascar Pinky	20—35	10—11

The following figures for "loss on washing" are from

[1] *Jour. Soc. Chem. Ind.*, 1894.
[2] *Loc. cit.*
[3] *India-rubber World*, December, 1906.

other sources, and are included so as to give a general idea of the Asiatic products :—

	Loss on Washing.	Resin in Washed Rubber.
Asiatic—	Per cent.	Per cent.
Rangoon	20—30	5—7
Penang	10—30	6—7
Borneo	20—60	7—8
Assam	10—45	5—9
Java	10—40	6—7

All these are sold in two, three, or more grades, according to their general purity, and it is evident that the figures for loss and resin will vary considerably in the different grades. The raw rubber production of the world for 1906 has been calculated at 65,000 tons, of which 41,000 tons came from tropical America, 22,000 tons from Africa, and 2,000 tons from Asia.

CHAPTER III.

CHEMICAL AND PHYSICAL PROPERTIES OF INDIA-RUBBER.

India-rubber—that is, the purified unmanufactured body—is a tasteless opaque white substance having a more or less pronounced odour, characterised to some extent by its mode of coagulation; in smoked Para the smell of creosote is always perceptible, while the odour of rotten cheese is generally associated with low class brands from Africa and Central America. The specific gravity has been variously stated. Faraday gives it as ·925, Julian as ·920, Weber ·915 to ·931, while the author, as the result of careful determinations made on Para rubber cleaned and compressed into a block, has found it to be ·924.

Chemically speaking, the analyses made respectively by Faraday, Ure, Greville Williams, Berzelius, Adriani Gladstone and Hibbert, and by Weber amongst the most recent investigators, show that it must be considered a hydrocarbon, of the terpene type, $C_{10} H_{16}$, this formula representing the composition of turpentine. As a matter of fact, however, india-rubber is never found entirely free from oxygen, this element being contained in a small portion of the whole which is insoluble in the ordinary solvents. This insoluble body was first described by Payen and has been studied closely by more recent observers. The statements of some authors as to the amount of this

constituent present in ordinary rubber are no doubt greatly exaggerated, Gladstone and Hibbert having found only 4 per cent. of it in Para rubber, and Weber, as the result of repeated experiments, from 3 to 6·5 per cent.

Expressed in percentages, the composition may therefore be taken to be, if we adopt the figures of Gladstone and Hibbert—

	Per cent.
Carbon	87·46
Hydrogen	12·00
Oxygen and ash	·54
	100·00

Into the protracted researches which have been made by various chemists, in recent years, to determine the correct formula and the molecular weight, it is not proposed to enter. Their discussion would lead into scientific regions in which those who are not equipped with a knowledge of organic chemistry would find it difficult to make any headway. The limited space available will, therefore, be utilised for the discussion of matters of easier comprehension, and of more general import with regard to the manufacture.

India-rubber is quite insoluble in water, but it will absorb about 25 per cent. into its pores after soaking for some time. As showing that rubber is not entirely impervious to water, mention may be made of an interesting experiment carried out by Hancock, who having filled a rubber bag with water and sealed it hermetically, found the weight to continually decrease, until after thirty years it proved on being cut open to be quite dry Alcohol is also absorbed

by india-rubber, but has no solvent action upon it. With regard to acetone, which was first suggested by Weber as a useful medium in rubber analysis, and has been stated by him to have no solvent action whatever upon the rubber, it would appear from a recent statement of Ditmar that it is not above suspicion in this respect, and that, in fact, it will on occasion dissolve appreciable quantities of rubber. These statements are given for what they are worth; that the point is an important one will be at once recognised by those who use this solvent largely in the analysis of india-rubber goods. Ether, chloroform, carbon tetrachloride, turpentine, carbon bi-sulphide, petroleum spirit, and benzene, and its homologues found in coal tar naphtha, dissolve rubber readily, though only the two last-named have any regular application in the manufacture of india-rubber goods. The term solution is not a particularly good one in this connection. It implies, in technical circles, a viscous mass resulting from the swelling up of the rubber in the solvent. As a colloid substance, distinct from what is crystalline, it cannot be said to form true solutions, but as we are discussing technical matters the common designation will be adhered to. Lack of volatility, extreme volatility and consequent danger from fire, or the item of expense are the main causes which have militated against the adoption of solvents other than those derived from coal tar or petroleum, the first employment of which by Macintosh gave rise, as we saw in the first chapter, to the establishment of the rubber industry. Mention ought not to be omitted of the partial use of shale spirit as a solvent; this is a product of the paraffin shale industry of Scotland, and differs chemically from the coal tar and petroleum naphthas.

These solvents find their principal application in the waterproof branch, and special reference to them will be found in another chapter. A very important property of india-rubber, and one which hardly needs mention, is its elasticity. It possesses this property to a much greater degree than any other known substance.

Some scientific authors prefer to use the term distensibility for that of elasticity, saying that the general use of the latter by the rubber manufacturers and the public arises from a misconception of facts. They point out that the hardest steel is more perfectly elastic than a piece of india-rubber. This may be strictly true and capable of experimental demonstration, but at this time of day it seems hopeless to expect that any reformed procedure in this respect would be supported by the public, however the manufacturers might come to regard it. It is proposed, therefore, to use the expression "elasticity" in this volume.

Action of Heat and Cold upon India-rubber.—At temperatures below the freezing point india-rubber loses its elasticity, becoming quite rigid, and indeed on immersion in liquid air it becomes as brittle as glass.

At higher temperatures it becomes increasingly soft and plastic until, at a point which varies according to the quality of the rubber, it melts into a sticky mass which cannot again assume the form and characteristics of the original substance. The temperature at which it begins to melt may be put at about 350° F., and after 400° F. it passes into the condition of an oil. On destructive distillation it yields a series of oils first investigated by Himly, Bovchardat and Greville Williams. The product of this

distillation finds considerable reference in old treatises on india-rubber, but although it has been mentioned as suitable for many applications, it does not appear to have ever come into regular use, and it must be looked upon merely as of scientific interest. Some years ago the author prepared a quantity by distillation in an iron retort fitted with a condensing arrangement. A considerable amount of charcoal was left in the retort, which was finally heated to dull redness. The crude distillate was redistilled into several fractions, the lightest of which was of a pale lemon colour and had a pleasant ethereal smell. Samples of these oils were tried for purposes for which they had been recommended, but in all cases the results were unsatisfactory. What has been termed caoutchouc oil, used in the German army as a rust preventative, is a solution of rubber in linseed oil, and is, therefore, quite a different substance from the true oil of caoutchouc, the pure distillation product.

Reverting to the effect of low temperatures upon india-rubber, reference may be made to an erroneous statement to be met with in some of our text-books on physics. It is to this effect :—"India-rubber, unlike the great majority of substances, contracts when it is heated." That there must be something wrong about this is evident to the practical man who is familiar with the expansion of india-rubber goods when being vulcanized in moulds, and the explanation of the anomaly is to be found in the omission of the writers to use the qualifying adjective stretched. The fact is that rubber in a normal condition expands on heating, but if it is distended and then exposed to heat it certainly does contract. This was demonstrated by Tyndall, who used a tube of vulcanized rubber stretched to three times its length.

Another example of this is seen by taking a thin strip of rubber cut from a Para "biscuit," and stretching it out. It will remain in this elongated condition for any length of time, provided it is not warmed. If, however, it is merely placed in the hollow of the hand, it will commence to wriggle about and contract to its original dimensions. On again being heated it will expand in the ordinary course. Rubber in many of its manufactured forms is under tension; this is notably the case with fine cut sheet, and when this is subjected to what is known as "shrinking" in the course of the manufacture of certain goods, the result attained is contraction in one dimension, and expansion in another. Thus a piece of cut sheet rubber measuring 738 square inches showed after five minutes "shrinking" on the steam chest a superficies of 776 square inches when it had cooled down. To leave this point and to pass on to another of some scientific interest, it was noted by Lord Kelvin, more than forty years ago, that rubber becomes hot when stretched instead of becoming cooler, after the manner of metals. Some experiments on this subject were also published by Joule in the *Philosophical Magazine* for 1857. This action can be readily observed by stretching a piece of rubber on the bulb of a delicate thermometer.

The specific heat of india-rubber has been determined by the author and W. W. Haldane Gee,[1] and found to be ·48, the same as for turpentine.

The thermal conductivity of rubber compared with some other substances is here given, the figures representing units of heat transmitted per square foot per hour by a plate

[1] Proc. Man. Lit. and Phil. Soc., 1891.

1 inch thick, the two surfaces differing in temperature by 1° F. The figures are due to Peclet.

Copper	515
Iron	233
Marble	28
Glass	6
Oak	1·7
India-rubber	1·37
Blotting-paper	·27

Thus it will be seen that when vulcanizing in iron moulds the heat will be transmitted through the iron and the rubber in the ratio of 233 to 1·37, *i.e.*, 170 times more quickly through the iron than through the rubber.

The Diffusion of Gases through Rubber.—The fact that india-rubber is capable of absorbing gases in its pores was announced in 1831 by Dr. Mitchell, of Philadelphia, his experiments showing that those gases which were most easily liquefied by pressure penetrated into the rubber the most readily. Taking ammonia as unity, he gave the following table :—

Equal volume of gases.	Time.
Ammonia	1 min.
Sulphuretted hydrogen	2½ ,,
Cyanogen	3¼ ,,
Carbonic acid	5½ ,,
Nitrous oxide	6½ ,,
Olefiant gas	28 ,,
Hydrogen	37½ ,,
Oxygen	1 hr. 53 min.
Carbonic oxide	2 ,, 40 ,,

In 1867 the matter was closely studied by Graham, Master of the Mint, in the course of his researches on colloids, and he came to the conclusion that the passage of gases through rubber could not be ascribed to simple gaseous diffusion, but must be a case of liquid diffusion, the liquefaction of the gases taking place in the pores of the rubber. Of ordinary gases he found carbonic acid to penetrate the most quickly, and he gave the following table with this gas as unity.

Name of gas.	Time ratio of diffusion.
Carbonic acid	1
Hydrogen	2·47
Oxygen	5·316
Marsh gas	6·326
Air	11·850
Carbonic oxide	12·203
Nitrogen	13·585

Thus it will take thirteen and a half times as long for a certain volume of nitrogen gas to pass through a film of rubber as it does for the same volume of carbonic acid.

As far as the rubber manufacture is concerned, the significance of these figures may be considered as limited to the hollow ball branch, both ammonium carbonate and air under pressure being used to bring about inflation. That diffusion is continually going on may be demonstrated by thoroughly washing a lawn-tennis ball and suspending it in a sealed jar containing some Nessler solution—a delicate test for ammonia—when the brown discolouration indicative of ammonia will be seen after a short time.

Action of Alkalies and Acids.—Caustic alkalies, as would

be expected in the case of a hydrocarbon, have no appreciable effect upon rubber, though where there is resin present, it is dissolved to some extent. Neither have dilute hydrochloric or sulphuric acids any action, though concentrated sulphuric acid acts upon it energetically.

Nitric acid acts upon it in even very dilute solution in the course of time with the formation of nitro-resinous bodies. If the oxidation is carried far enough, the whole of the rubber can be converted into oxalic and carbonic acids. In some work the author did on this subject in 1891,[1] there was obtained by the slow oxidation of pure sheet rubber with dilute nitric acid a yellow body which gave on analysis :—

	Per cent.
Carbon	50·50
Hydrogen	6·13
Oxygen	37·94
Nitrogen	5·43
	100·00

At that time other matters being more pressing, the investigation was dropped. Since then, however, a considerable amount of work has been done by Harries, Weber, and others, and the existence of definite nitro derivatives has been established.

Much the same progress has to be reported with the halogen derivatives, the first definite chlorine and bromine compound having been prepared by Gladstone and Hibbert in 1888, though it is interesting to note that a process for preparing white rubber solution by passing chlorine into a

[1] Proc. Man. Lit. and Phil. Soc., 1891.

solution of rubber in chloroform was described by Hurtzig about thirty years ago.

The Action of Oxygen.—Of more general interest and importance is the action of oxygen upon india-rubber, as it is to this element that the decay of india-rubber goods is mostly attributable. Attention seems to have been first called to the subject by Spiller,[1] who found that rubber which had decayed on exposure to the air contained a quantity of a resin containing 27 per cent. of oxygen. Later on, Burghardt[2] stated that besides this resin another oxidation product, insoluble in alcohol and unsaponifiable by alkalies was produced by atmospheric oxidation. In 1889 the author (*loc. cit.*) pointed out that these oxidation products differed considerably from the resins naturally occurring in the different commercial brands of rubber, the oxygen contents of these latter being from 10 to 14 per cent.

Resins are not attractive bodies for the chemist to work upon, and the labourers in this particular field have been few. There is certainly room for further research into details, although the main facts as far as the trade is concerned may be considered established. As a result of the work which has been done, it may be taken that oxygen in the presence of the actinic rays is decidedly injurious, and that the more the india-rubber is protected from the light the longer will its life be. Further, the more the rubber is "worked" on the washing roller or in the masticator, the greater is its tendency to oxidation. Opposite views have been expressed on this point, but it would seem

[1] *Jour. Chem. Soc.* [2] iii. 44.
[2] *Jour. Soc. Chem. Ind.*, 1883.

that they are founded on unsatisfactory data. Burghardt (*loc. cit.*) gives a series of analyses of elastic thread showing the increasing oxidation that takes place with time. Though these figures undoubtedly are representative of what goes on, it is surely incorrect to say that normal thread contains no oxygen at all. The late Dr. Gladstone informed the author that he found oxygen to the amount of 2 or 3 per cent. in all his analyses of raw rubber, and the work of more recent investigators all goes to confirm this. It has been rather generally supposed that vulcanized rubber is more sensitive to the insidious action of air and light than is the unvulcanized; but this has been controverted by Weber, whose experiments certainly support his contention as far as they go. There is plenty of proof, however, that raw unmanufactured rubber has a much longer life than the vulcanized rubber. Some of the samples of raw Para rubber in Kew Museum must be now over sixty years old, and the author has a specimen in his possession guaranteed to be forty-five years old and still quite sound. This is in the form of drawn-out thread, and it has been exposed to air all the time, though shielded from sunlight.

With regard to vulcanized rubber, evidence is wanting of anything like such longevity. In the face of this experience then, the statement that unvulcanized rubber is more readily oxidised by atmospheric agency than is the vulcanized substance must be taken with some reservation, and with due regard to all the particulars involved. It is evident that as regards liability to decay we must distinguish between raw rubber as it comes from Brazil and unvulcanized rubber which has gone through the factory processes of washing and drying. If we add to these

rubber which has been properly vulcanized by the aid of sulphur and heat we have three distinct substances, and the liability of each to oxidation or decay will depend very largely upon the conditions under which the oxidation takes place. Hence the exhortation as to caution in accepting as axiomatic with regard to raw or vulcanized rubber generally, what has been stated by this or that observer as the result of special experiments. On the present occasion the subject cannot be gone into more fully, and it will suffice to summarise the results of experience by saying that vulcanized rubber goods have only a certain life; this life in the case of goods which are not exposed to heat or friction depends to a considerable extent upon exposure to the actinic rays—the less the exposure, the longer the life. Wherever possible, then, rubber articles when not in use should be stored in a cool, dark place. This statement invites a special word of warning to those dealers who, in order to attract the attention of the passer-by, expose their goods in the shop windows to the strong sunlight. Of course, there are obvious difficulties in directing the public gaze to what is stored in a dark cellar, but all the same it seems advisable to draw attention to the risks involved in the ordinary procedure, and, as for the rest, well, the shopkeepers must be left to work out their own salvation.

Vulcanized rubber goods which are undergoing oxidation have quite a distinct odour from those which are sound, and this odour increases in power as the resinification proceeds. In the case of thin coatings of compound rubber, such as are to be seen in military ground sheets, the different stages of oxidation can be seen in the gradual change to a plastic

substance which sticks to the fingers and on to a final product which may be easily powdered. At this stage the rubber is of no use to anybody, not even the waste rubber merchant, with whose proceedings we shall be concerned in a subsequent chapter. After seeing the above the enquiring reader may be inclined to ask whether some protective coating could not be applied to the rubber so as to safeguard it against the insidious attacks of oxygen. The answer to this is that various means have been proposed but have resulted in nothing. If rubber had a rigid surface the difficulty would probably not be great, but seeing that elasticity is a prominent feature in most goods, there is of course a pronounced tendency for a protective coating to crack off when the rubber is under pressure or tension. All the same, it cannot be said that the subject has received that meed of attention which it would seem to merit, and it is not desired to discourage further efforts, although in regard to this matter it is not at all certain that the discoverer of the elixir which is to indefinitely prolong the life of rubber goods would be received with acclamation by the manufacturers or by those who are interested in india-rubber plantations. Besides the brown resin, resulting from oxidation, decayed rubber always contains 5 to 10 per cent. of water. From what has been said as to the action of oxygen, it follows almost as a matter of course that ozone has a strongly destructive action upon rubber.

The Action of Grease upon Rubber.—Users of rubber goods, especially motor car owners, have been pretty generally made aware of the fact that grease or oil is injurious to rubber. Although the fatty oils, such as palm

oil, may be considered the most injurious, yet almost any oil or fat is dangerous in that it softens the rubber and partially dissolves it to form a sticky mass. In a general way it may be stated that the damage done by oil is directly proportional to the thickness of the rubber, considerations of subsidiary, though not unimportant influence, having relation to temperature and the general conditions of exposure to sunlight. Those who have only heard of oil as an enemy in connection with rubber may be surprised to learn that it is a regular constituent of some classes of goods, the heavy petroleum oil being most commonly employed, though fatty oils are also used in this connection. The injurious action of oil upon films of rubber came into prominent notice about thirty years ago in connection with the waterproofing of woollen cloths. Oil is regularly used in the weaving process, and the decay of a good deal of waterproofed cloth was traced to the presence of this oil which sometimes amounted to 4 or 5 per cent. Precautionary measures were then adopted, and it became customary for waterproofers to test their cloths and reject any which showed over 2 per cent. of oily extract. At the present time such testing is but rarely resorted to because those firms who make a speciality of textures for waterproofing purposes guarantee that all their woollen cloths have been scoured until practically free from oil. For another reason the subject is of less importance than it used to be, and this is because the cold curing process as generally used twenty years ago has been succeeded by the Dry Heat process and the rubber is not so likely to be damaged by the presence of a small amount of fatty matter. The action of oil upon rubber has been studied in detail

by Thomson,[1] who experimented with elastic thread and found that sperm tallow and neatsfoot oils at 100° F. completely dissolved the rubber after some months, while cotton seed oil, olive oil, cod liver and seal oils only caused it to swell up, and that the only oil which had practically no action was castor oil. Thomson's experiments, though of some scientific interest, were carried out under conditions quite foreign to those which rubber goods are subjected to in practice, and from the very contradictory statements which have been published regarding the action of fatty matters on vulcanized rubber, especially as to whether or no they facilitate oxidation, it is clear that further work in this direction is needed. No statements, then, of a positive nature will be made here. All the same it is advisable in the light of experience not to allow rubber goods to come in contact with oil, as in many cases it may be expected to prove decidedly injurious.

The Action of Copper upon India-rubber.—Copper, either in the form of the metal, the oxides, or the soluble salts, has a decidedly injurious action upon rubber. This was first pointed out some twenty-five years ago by Burghardt, and subsequent investigations have shown that the alarm note first sounded was by no means unjustified. Indeed it has been proved that exceedingly small quantities of copper or its salts, much smaller than was originally supposed, have the power to cause the decay of certain rubber goods. Exactly what the action is has not been entirely cleared up, but in the case of metallic copper it has been plausibly attributed to oxidation induced by the dissolved oxygen in the copper. The deleterious action of the copper is much accelerated in the

[1] *Jour. Soc. Chem. Ind.*, December, 1885.

presence of grease, or in fact any substance capable of acting as a solvent. Weber has drawn attention to the fact that goods cured by Dry Heat, that is, speaking more particularly of textures, are less likely to be damaged by copper than those which are cold cured. In the former case the insoluble sulphide of copper is formed, and in the latter soluble salts. In the light of the experience of insulated rubber cable manufacturers this statement of Weber's regarding the innocuous behaviour of sulphide of copper must not be read too closely. In the cable manufacture it is the universal rule to coat the copper wire with tin in order to prevent the sulphur from attacking the copper to form copper sulphide. With regard to the rubber manufacture proper, the only trouble experienced with copper has been in the water-proofing branch and elastic webbing, the copper being found associated with the black and brown dyes of certain fabrics. Of course the quantities present are only very small and one must be cautious in making comparisons with the cable industry, where the amount of copper available for acting on the rubber is very much larger. Still, whether the copper sulphide is to be considered harmful or not, it is a good rule to bar the presence of copper altogether, and at the present time it is quite the exception to come across it in any goods intended for use with rubber. As in the case of grease, the manufacturers of textiles for the proofing trade have arranged their dyeing procedure so as to obviate the necessity of using copper salts, and trouble from this source seems to be altogether a thing of the past. Any action which other metals exert upon rubber is too trifling to call for any notice and there does not seem to be any evidence of the inimical action of chromium salts as has been stated to be the case.

India-rubber stands high as an insulator of electricity and consequently has a wide application in the electric cable manufacture. Its specific inductive capacity, otherwise known as the electrostatic capacity and the dielectric constant, may be taken as 2·22 for the pure substance, the varying figures to be met with evidently having reference to vulcanized and compounded rubbers. At the present time it is not uncommon to come across insulating rubber containing over 60 per cent. of mineral matter, and for these the specific inductive capacity may be 4·6 or even higher. The same thing occurs with most insulating substances which may vary in grade composition or degree of refinement to a considerable extent. Unless, therefore, we have some knowledge of these various and variable factors, any figures relative to specific substances must not be read too closely. As the most recent publication on the subject, Abbott's "Transmission of Energy" has been drawn upon for the following table, dry air as the most perfect insulator being taken as unity:—

Name of Material.	Specific Inductive Capacity.
Air	1
Ordinary glass	1·90 to 3·013
Flint glass, extra dense	6·55 to 10·10
India-rubber	2·22 to 3·70
Ebonite	2·284
Gutta-percha	2·580 to 4·20
Sulphur	1·93
Shellac	1·95 to 2·740
Paraffin	1·98 to 2·00
Ozokerite	2·13

Another important electrical constant in connection with light and power cables is the insulation resistance which is expressed in terms of megohms per mile. This varies with the temperature and also with the quality of the rubber. Speaking generally, it has been shown that unvulcanized rubber is superior to vulcanized, and that the effect of compounding is to decrease the resistance.

A third electrical constant is the dielectric strength, and some figures by Gray, showing the inferiority of rubber compared with mica, are here given.

Material.	Maximum Dielectric Strength in Kilowatts per Centimetre.
Glass	285
Hard rubber	538
Soft rubber	476
Mica	2,000
Micanite	4,000

CHAPTER IV.

VULCANIZATION.

It will be convenient at this juncture to say a few words explanatory of vulcanization, the importance of which process in the technology of our subject has already been briefly alluded to in the first chapter. It was discovered by Charles Goodyear, of Newhaven, United States, America, in 1839, after many years of experimenting, that rubber when mixed with sulphur and then subjected to a temperature above the melting point of the latter (239° F.), underwent a remarkable transformation in its physical and chemical properties. It was no longer soluble in the ordinary media, such as turpentine, chloroform and naphtha, neither was it influenced by such degrees of heat and cold as profoundly affected ordinary rubber. Further, and more important still, its elasticity was considerably increased. Such were the main characteristics of the new body, and it is not surprising that their importance led to instant recognition on the part of others engaged in the rubber manufacture. Prominent among these was Hancock, who had some small pieces of Goodyear's rubber given to him by Mr. Brockedon, a partner in Charles Macintosh & Co., in the autumn of 1842. Hancock was in complete ignorance of the means whereby Goodyear had effected his end, nor did he have the samples analysed. Setting to work,

however, with indomitable energy to imitate them, he succeeded in so doing in 1843, and in 1844 took out his patent for the use of the sulphur bath. *A propos* of Goodyear's discovery, the information comes on reliable authority that the rubber contained white lead as well as sulphur, and that Goodyear himself did not attach that degree of importance to the sulphur which it was later demonstrated by Hancock to possess. But be this so or not, it is clear that to Goodyear belongs the first discovery of vulcanization. Hancock, although deserving every credit for his rediscovery, having the valuable incentive that what has been done once can be done again. Though the point of actual priority of discovery, however, may be considered settled, there can be little doubt that its application to the trade generally is due to Hancock rather than Goodyear, for very little appears to have been done between 1838 and 1844. It was soon recognised that Goodyear's process of mixing the sulphur intimately with the rubber, and then exposing the mixture to heat, was of far more general applicability than was Hancock's method of putting the rubber in a bath of molten sulphur. Still the latter had a considerable application for certain purposes, and, contrary to what has been stated by recent authors, it is still in regular use, in England and France at all events. With regard to the term vulcanization, this has been attributed to Goodyear by some authors. It was Mr. Brockedon, however, who first suggested the name of the deity of fire as appropriate in this connection. Vulcanization is now a dictionary word in very general use in the trade, though as applied to the cold process to be described directly it is certainly objectionable, as embodying a contradiction of terms.

Sulphur was the substance used by the original investigators to attain the desired end, and to this day the element remains supreme for the purpose, despite the very numerous attempts by subsequent investigators to effect its substitution. Exactly what the reaction is that takes place during the vulcanization process cannot be said to be satisfactorily settled yet, despite the attention which the topic has received in recent years. Former writers talked glibly about the production of a sulphide of caoutchouc, but without bringing forward any experimental evidence of their assertions, and at the present day, the once widely-held theory of a substitution compound—that is where one or more atoms of hydrogen have been replaced by sulphur—has been abandoned as untenable. Probably the theory advanced by C. O. Weber, to the effect that vulcanized rubber is an addition product, is most correct. Taking the india-rubber hydrocarbon as $C_{10}H_{16}$, this would pre-suppose the vulcanized rubber to be some multiple of $C_{10}H_{16}S$, but the matter is of too abstruse a nature to warrant further discussion here, and we may proceed to matters of more practical import. It is generally supposed that not more than 3 per cent. of sulphur is chemically combined with the rubber, the remainder existing in the free condition in the pores thereof. This figure, however, must not be read too closely, recent research having shown that much depends upon the details of the process.[1] As a rule, however, about 3 per cent. is found to be left in rubber which has been subjected to a prolonged boiling in caustic soda solution which dissolves out the free sulphur. The exact amount of

[1] Weber has obtained a vulcanized rubber with 7 per cent. combined sulphur.

combined sulphur present does not affect, to any appreciable degree the elasticity, though an excess of free sulphur must in many cases be considered as injurious. Until recent years, practically no attention had been paid to the scientific side of vulcanization, and even now the absence of complete harmony among the investigators in the results obtained, renders it necessary to exhibit a certain reserve in putting on record what amounts to no more than a working hypothesis.

Properly vulcanized pure india-rubber will stretch to seven times its length without breaking and return to its original dimensions when released from stress, thus showing a property possessed by no other known substance. This statement refers, of course, to pure rubber and sulphur, and not to heavily compounded rubber.

The advantages of vulcanization can hardly be over-estimated, but it must also be recognised that vulcanized rubber has only a limited life. Owing doubtless to the presence of the sulphur, especially the free sulphur, it is very prone to atmospheric oxidation, the rapidity of which depends largely upon the conditions to which the goods are subjected, as also upon their composition and mode of manufacture. The phenomenon of an old macintosh as stiff as a board, or of a rigid tobacco pouch are familiar illustrations of this oxidation process.

Methods of Vulcanization.

There are two or three processes of vulcanization which are in regular use, and a whole host that have been proposed at one time or another and either never put into operation at all, or only to a very partial extent, and subsequently

discontinued. With regard to these latter, there seems no object in taking more than passing notice of one or two of the most prominent, those which are alive claiming our best attention.

The usual method of incorporating the necessary sulphur with the rubber is on the mixing rolls which are described elsewhere. For this purpose, sublimed flowers of sulphur in a fine state of sub-division and free from crystals and sulphur acids are used. By the mixing process, the sulphur is intimately incorporated with the rubber or rubber compound as the case may be, and the "mixing" having been made into the goods required has now to undergo the heating process, for so far it has undergone no change, being simply a mixture. The forms of vulcanizing plant vary according to the nature of the goods, but in principle they are all the same in that the rubber is raised to a temperature varying from 265° F. to 285° F. for a greater or less length of time, according to the special circumstances and needs of each case. It will be more convenient to refer to the particular forms of vulcanizing plant when dealing with the goods for which they are chiefly used.

Another mode of mixing the sulphur with the rubber will be instanced when we come to elastic thread and waterproof textures.

A third method used only in the case of small articles made of pure rubber, is what is known as the sulphur bath, the form of apparatus originally used by Hancock in his experiments. This is merely an iron pan in which brimstone is kept in a molten condition by means of a fire or a steam jacket. The rubber when placed in the pan absorbs a certain amount of the sulphur into its pores, turning a

brown colour. Much the same result is obtained according to Chapel and various other authors by Girard's process in which the goods are immersed into a hot solution of persulphide of potassium or sulphydrate of lime under pressure. It is possible that this process is in use in France, but the author could never get any satisfactory evidence of its application anywhere, and much doubts whether it has ever been used in Great Britain.

Parkes' Process.—Another and quite distinct process of vulcanization now claims attention, namely, that invented by Parkes in 1846, and more appropriately known as the "cold cure." Compared with the sulphur and heat process it is of distinctly limited application, as it is only suitable for rubber in thin sheets. It consists in dipping the goods into a mixture of bi-sulphide of carbon and chloride of sulphur, generally 40 of the former to 1 of the latter. The action takes place in the cold and is of very limited duration, a few seconds being usually all that is required. The active agent is the chloride of sulphur, the part played by the mephitic liquid, bi-sulphide of carbon, being merely that of a solvent and a dilutant. It used to be thought that the chlorine was the element which brought about the change, but according to the researches of Weber it would seem that the sulphur in this, as in the Goodyear process, is the responsible agent, though both chlorine and sulphur combine with the rubber to form addition products such as may be expressed by the formula, $C_{10}H_{16}S_2Cl_2$. A danger connected with this process is the development of free hydrochloric acid arising from decomposition of the sulphur chloride by moisture, and it is now customary to reduce this source of trouble to a minimum, either by giving the

freshly vulcanized rubber a good washing or, where this is not permissible, to expose it to the vapours of ammonia.

That the use of this process is objectionable from a hygienic standpoint is undeniable, the bi-sulphide of carbon vapour having a very serious effect upon the health of those subjected to its fumes. Under the clauses of the Factory Acts passed in 1896, its application is now hedged round with stringent regulations which cannot be considered at all superfluous by those who know the havoc wrought in the past, though they may possibly be described as unnecessarily irksome by those responsible for their due observance. Moreover, now that continental countries have fallen into line with England in this matter, the complaints which were at first heard as to the serious effect on the particular trade concerned, have quite lost their significance. At one time this process was much more largely used, than is at present the case, for the vulcanization of waterproof textures; when, however, the Dry Heat method began to be largely adopted in 1884, the cold curing with chloride of sulphur fell largely into desuetude. A name in common use for this process, it may be mentioned, is "sincaloring," derived from *sine calore*, though its derivation is not always respected by those who employ it. It is sometimes written "sincolor," and the form "sinklor" also is to be met with.

Another method of vulcanizing with chloride of sulphur should be mentioned, though it is not of wide application. The goods, nearly always articles made from pure sheet rubber, are hung up in wooden zinc-lined chambers with tightly fitting doors. A small amount of chloride of sulphur

is placed on a dish and evaporated by the heat of steam pipes which are placed on the floor of the chamber. The acid vapours are readily absorbed by the rubber, and when, after the lapse of a certain time, the chambers are opened no smell of chloride of sulphur can be perceived. Goods treated in this way are really only surface cured, and, except for special purposes, the vulcanization with heat and sulphur gives a better and more durable article.

A year or two ago some stir was aroused by the announcement from America of a process of electric vulcanizing, though so far no practical developments have to be recorded. Moreover, as the only part which the electricity was to play appeared to be in the capacity of a heating agent for vulcanizing goods containing sulphur, there is no new principle involved, even supposing that it proved satisfactory in practice. With regard to the Doughty process of vulcanizing in a short time, at a high temperature, the case is different, as the process has been largely adopted at the works of the Dunlop Rubber Company, this firm having obtained sole possession of the patents. Although the opinion was widely held, a few years ago, that the use of temperatures as high as 320° F. must inevitably prove destructive to the rubber, this has certainly been falsified in the event. The process is not adapted for rubber of any thickness, as it would burn the outside before the interior was vulcanized, but it is largely used for cycle tyre covers by the Dunlop Company at Birmingham, and also at their continental and Australian works. The actual time of vulcanization is three minutes at 175 lbs. pressure or 370° F., the whole process, including putting in the tubes and taking them out, lasting only five minutes. Moreover, the necessary shape is given to the

cover during the vulcanizing. The possession of this patent undoubtedly puts the Dunlop Company in a much stronger position, as regards output, than is the case with their competitors, who are restricted to older and more lengthy methods.

Since the extension of the motor tyre business and the general use of vulcanizing apparatus by repairers throughout the country, considerable looseness has attached to the way in which the term "vulcanization" is used. We have seen that all the processes of vulcanizing, as carried on in the india-rubber works, involve the use of sulphur or of chloride of sulphur, and it is incorrect to talk of vulcanizing where neither the ordinary hot nor cold processes are employed. This, however, is done by not a few connected with the tyre repairing trade in reference to specialities they are desirous of bringing before the public eye. It certainly seems desirable, in the interests of a clear understanding, that processes of attachment, or of rejuvenation, should, when carried out without the use of heat and sulphur in combination or of the cold cure, be designated by some term other than vulcanization.

In concluding this important topic it may be emphasised that in whatever way the process of vulcanization is carried out, it is at once the most important and the most delicate which the factory manager has to control. The results obtained are influenced not only by the amount of sulphur present, the time and the temperature, but also to some extent by the character of the rubber, and in the case of compounds by their quantity and nature. It will be seen at once that very considerable technical knowledge is demanded for the control of an operation which, if

unskilfully carried out, may easily lead to a loss of hundreds if not thousands of pounds in a short time. The difficulties of everyday work are not great when established procedure has to be followed, variation in the raw rubber being the only cause from which trouble may arise. It is rather in the production of new classes of goods and in the constant changing of the composition caused by alteration in the market price of the raw material, and also in the constant demands for a cheaper article that the ingenuity of the factory manager is severely taxed. The premature end of many rubber goods has frequently formed a fruitful source of speculation, and although in such cases it is often a matter of the very greatest difficulty to assign a cause, it is probable that defects in vulcanization are as often as not the primary source of trouble.

It may be taken as beyond cavil that excess of sulphur is responsible for a good deal of trouble in mechanical goods used for steam purposes. It has been mentioned on page 84 that only a comparatively small amount of sulphur, averaging, say, 3 per cent., is chemically combined with the rubber. A larger quantity than this, nearer in fact to 10 per cent. on the rubber by weight, is always used in practice, as otherwise the vulcanization would take up too much time. In some classes of goods, notably those consisting of rubber and sulphur alone, or containing red sulphide of antimony in addition, it is customary to immerse the articles in a hot solution of caustic soda, in order to dissolve out the excess of sulphur. It has often been urged against this procedure that it renders the rubber somewhat porous and more susceptible therefore to atmospheric

oxidation. That this objection has not much weight, however, is conclusively shown by the use of the process for the last fifty years by the foremost firms in the trade, who have doubtless satisfied themselves of its economic advantages. It is obvious that it cannot be used in the case of thick or heavily compounded goods, and in these the excess sulphur has perforce to remain, generally showing itself after a short time on the surface as a white efflorescence, to use a common, though perhaps not a scientifically correct, term for the phenomenon. The sulphur is at first in the colloidal or uncrystallized condition, though after a time it assumes the crystalline state. The objections to this efflorescence are sentimental rather than rational, and though in many cases the removal of the sulphur is demanded by the retailer because it is a bar to the sale of the goods, there are still many and notable instances where no such desulphurization is called for or practised, and where the goods give every satisfaction in their specific applications. Although in England caustic soda is almost universally used for desulphurizing, on the Continent potash in the form of the American black ash is much in favour, although it is more expensive. This is because of the smoother surface it imparts to the rubber. A rather troublesome feature with regard to this desulphurizing process is the difficulty attending the disposal of the waste liquor. This consists of a number of sodium salts, of which the sulphide predominates, and there is always some free caustic left. In the case of elastic thread there is also a good deal of shellac in solution. Nowadays urban and river authorities exercise more supervision over trade effluents than was the case in the past, and trouble has

arisen on more than one occasion with regard to this caustic liquor. Like a good many other trade effluents it can be rendered practically innocuous without any great expense or trouble being incurred, though the idea which has taken root in some minds as to its being utilised to advantage ought, it would seem, to be dismissed. The author went pretty fully into the matter some years ago, and came to the conclusion that it could not be utilised to advantage. The quantities available at any particular time are insufficient for any continuous manufacture of precipitated sulphur or sodium salts, and then there is the organic impurity due to the shellac. Barring trials which have been made of it as a detergent in a workhouse, it does not seem to have ever had any practical application.

So much for the vulcanizing processes in regular and extensive use. With regard to the various other bodies which have been proposed as vulcanizing agents, the oxides of nitrogen are much too dangerous, and have never found any application, and much the same may be said with regard to chlorine and bromine. Iodine in the form of metallic iodides has had some use; Fawsitt, and also Weber, having taken out patents in connection with them for the dry heat of waterproof textures. As, however, these processes seem to be not now in use anywhere there is little attraction in dilating on them. There remains, however, a sort of vulcanizing process known by the name of acidizing, which dates back for many years and is still in partial use. The active agent is hypochlorous acid in dilute solution, obtained by the addition of a mineral acid to bleaching powder. Naturally no penetration of the rubber can occur in an aqueous solution, so the effect is

merely a superficial hardening. Washing in a weak ammonia solution serves to remove any excess of acid, and the process, at any rate, has the result of destroying the adhesiveness of pure rubber without rendering the use of French chalk necessary.

CHAPTER V.

INDIA-RUBBER PLANTATIONS.

The subject of cultivated rubber is attracting so much attention at the present time that it has been thought desirable to put all references to it in one chapter, so as to be easy of access to those whose chief interest in rubber lies in its future supply. The idea of supplementing the supplies of native rubber with the product of plantations is by no means a new one, initiative having been taken in India as far back as 1860, owing presumably to the decreased yield of Assam rubber from destructive methods of collection. It was not, however, until 1872 that the subject was recognised as of real importance, and in that year James Collins, an Edinburgh botanist, was instructed by the India Office to draw up a report concerning the rubber trees of America, and to ascertain whether they could be grown in India. In 1875, Robert Cross, of Liverpool, in concert with C. R. Markham, of Assam, was sent to Panama to collect seeds and cuttings of the Castilloa tree. He was also sent by the India Office the following year to Para to collect information about the trees yielding the Para and Ceara rubbers. His official report shows that he met with formidable difficulties in the course of his undertaking, but he succeeded in his main object. The seeds and cuttings which he obtained in his journeys were duly sown and planted at Kew, and in due

course dispersed over various botanical gardens in India and the Colonies, where, in many instances, they are now flourishing as trees. It would take too long to follow step by step the history of the movement thus inaugurated, but the matter continued to claim the close attention of Colonial Governors and curators of botanical gardens with varying degrees of success, and the work done can claim to be the foundation of what is now to be seen in the large number of existing plantations, from many of which rubber is now being regularly dispatched to the European markets. It is only a very few years ago that prominent American rubber manufacturers pooh-poohed the idea of putting money into rubber plantations; there was no object they said in paying for what a bountiful nature would perform free of cost. To-day, however, this tone seems to have been changed, and there is a general disposition among practical men in America, as well as Europe, to regard rubber planting if not as a necessity, at any rate as a desirable branch of economic botany, and likely to be a profitable one withal.

That acclimatised rubber trees can be successfully grown where the climate approximates to that of their original habitat is now an assured fact, and that they can be grown at a cost admitting of large profits is also now beyond dispute, but these are not all the factors which come up for consideration. Perhaps the question which is asked more frequently than any other by prospective investors in a new company, is whether there is any likelihood of the production from the new sources being so great as to bring prices down to an unremunerative level. Now this is a point on which it is almost impossible to speak with

precision, and the author instead of committing himself to any categorical statement of his prognostications will limit himself to the more cautious step of pointing out the main factors which must be taken into consideration. In the first place, with regard to the demand for rubber in the arts there can be no room for doubt that the remarkable increase in the demand witnessed in recent years will continue, even if not in the same ratio of progress; it may also be taken for granted that the output from America and Africa will not show a corresponding rate of increase, although the increase may be expected to be steady and maintained. As the figures for the exports of Para rubber sorts show a yearly rise since the commencement of the industry, and as the rubber has always found a ready sale at constantly increasing prices, we have here an adumbration of success for the plantation product. It is evident then that the present high price is due not to any indications of exhaustion in the crop, but to the interactions of the ordinary laws of supply and demand. It must not be overlooked by the zealous advocates of plantations in Ceylon and the Straits Settlements, that far from South America showing signs of depletion, there are vast quantities of rubber trees in Bolivia, Peru, and Columbia, which are at present untapped owing to scarcity of labour and lack of transport facilities. It is in this labour question that the planters have the advantage over the exploiters of the forest product; labour is not only cheap, but also, at any rate in Ceylon, it is abundant, and any failure in this respect need not come under consideration. The future for the plantations, then, more particularly as regards the payment of substantial dividends, would seem to depend a good deal upon the utilisation or the non-utilisation of the latent stores of rubber

known to exist in South America. In the face of the statements made by planters as to their actual costs of production (1*s*. to 1*s*. 6*d*. per lb.) it is clear that they would witness a considerable fall from present prices with equanimity, supposing that no disaster of an untoward nature overtakes them.

With regard, however, to the somewhat confident prediction of a planter, made in the course of conversation with the author, to the effect that we shall witness a parallel case to that which happened with the quinine industry in South America, the land of its birth, a discrepancy must be pointed out. The quinine plantations in Java and elsewhere have killed the old South American business certainly, but only because they produced an identical article at a much lower cost. Is this the case with the plantation rubber industry in Ceylon and the Straits? As far as things have gone up to the present it is not; expert opinion on plantation Para rubber being unanimous that it is deficient in strength compared with the Brazilian product. To some readers this may seem a somewhat startling statement, and inconsistent with the fact that the plantation rubber fetches the highest price in the market. This apparent inconsistency, however, may be easily explained. The higher price fetched by the plantation rubber is due to its greater content bulk for bulk of rubber. In other words, it is exported in a practically dry and clean condition, hardly losing 1 per cent. in washing, while the Brazilian "biscuits" always contain water, and traces of other matter, yielding a loss of from 15 to 20 per cent. When due allowance is made for this loss it will be found that the latter rubber is considered by the manufacturers the more valuable. So far, of course, very little plantation rubber has come upon the

market compared with the imports from Brazil, and it has been used for purposes such as solution making, where its cleanliness is an attraction, and its deficiency of nerve no disadvantage; but it has not yet replaced Para rubber in its most important applications, such as cut sheet and elastic thread.

This statement refers, of course, only to the time of writing, and it is quite conceivable that improvements in the methods of collection and coagulation may be made in the near future, which will put quite a different aspect upon affairs. In the meantime, however, what has just been said indicates that Brazil's sun has by no means set, nor is there any possibility of such an event until rubber of the same intrinsic merit is plentifully produced elsewhere.

Although at the present time planting in Ceylon is being confined almost exclusively to the Para tree (*Hevea Braziliensis*), it was the Ceara tree (*Manihot glaziovii*) which was at first chiefly grown. Very little success, however, was attained by the majority of tea planters, probably, to judge by reports of present growers, because of inexperience in methods of procedure. By way of completeness a few details of the present methods followed in Ceylon are appended, and those who wish to go further into the subject are advised to study the files of the *India-rubber World* and the *India-rubber Journal*, where original up-to-date articles are of frequent occurrence. Mention should also be made, in this connection, of the books by W. H. Johnson[1] and Wright,[2] though it should not be overlooked

[1] "The Cultivation and Preparation of Para Rubber," W. H. Johnson, F.L.S. Crosby Lockwood & Son, 1904.

[2] "Para Rubber," Wright, 1906. Ferguson, Colombo.

that events in this new industry have succeeded one another very rapidly, and methods but a year or two old have already become obsolete.

As a rule, the young trees which are tapped are at least five years old. With regard to the yield of rubber this is so variously stated by different planters that evidently a number of factors have to be taken into consideration, and it does not seem advisable to pass on figures of which the details are not available. The coagulation of the latex is carried out by diluting it with four times its bulk of cold water, and to every gallon of the diluted liquor one drachm of acetic acid is added. The liquor is then introduced into what is known as the Mitchie Golledge machine, in which it is churned until the coagulated rubber separates as a white spongy mass. This is removed, passed through rollers, sliced into shreds, and when dried in a current of hot air forms the "worm" rubber now becoming familiar in the London market. It will be noticed that no smoking of the rubber takes place as in Brazil, though a special apparatus for smoking has been designed, and is in partial use. In the preparation of the Ceylon biscuit rubber the diluted latex is allowed to stand in shallow vessels until coagulation takes place, the rubber being then passed through rollers and dried on shelves in a warm room. Very similar methods are followed in the Straits Settlements, and the Para rubber from that district has the same qualities and defects as the product of Ceylon. And, indeed, the characteristic lack of tensile strength, coupled with freedom from moisture and impurities, have been observed since the first plantation Para rubber was seen in Europe, as far as information is available. This was the case, at any rate, in a sample from

Mergui, India, which the author examined fifteen years ago. As to the cause of the lack of strength, whether it is due to the tree being tapped while immature, or to the rubber not being smoked, or to various other causes which have been suggested at hap-hazard as possible solutions, nothing can be put forward as yet with any degree of confidence. The matter, however, is receiving close attention at the hands of experts, and authoritative information ought to be forthcoming before long. Weber certainly seems to discount the idea that smoking the rubber will do all that is required, and expresses himself emphatically in favour of mechanical coagulation. This opinion awaits corroboration. A matter which has received some attention already, and deserves to receive more, is concerned with the nature of the soil. Planters of experience imagine that there may be trouble in store for Ceylon when the young trees attain adolescence, and their roots strike deeper down below the alluvial. They base their concern in this matter on what has happened with other crops cultivated in Central America. Although there seems no reason whatever to adopt a pessimistic tone with regard to this matter, as the conjecture is based on the dubious foundation of analogy alone, yet it seems important enough to warrant attention at the hands of those responsible for the future welfare of the plantations.

To such an extent have the prospectuses of Rubber Plantation Companies in Ceylon and the Straits and Malaya loomed recently in the public eye, that it is not surprising to find a general notion that the new industry is practically confined to these districts. By way of dispossessing the uninformed reader of this idea the following table, which is taken from the *Ceylon Observer* of July or

August, 1905, will be found useful. The figures, it should be said, only claim to be approximate, and should not be read too closely. The estimate gives about 150,000 acres under cultivation, and this no doubt has now considerably increased.

		Notes.
Ceylon	40,000	Mostly Para.
Malay Peninsula . .	38,000	do.
Borneo	1,500	Experimental Para.
Java	6,000	do.
India and Burmah . .	8,000	Young Para.
Mexico	10,000	Castilloa.
Brazil	5,000	Just planted.
Venezuela . . .	3,000	Just planted.
Ecuador . . .	2,000	Just planted.
Panama . . .	300	Castilloa.
Rest of Central America	2,000	Just planted.
Natal	50	Experimental.
Rhodesia . . .	100	do.
Rest of Africa . .	33,000	Mostly vines.
Tobago and West Indies	1,000	Castilloa.
	149,950	

The above notes have been inserted by the author.

From some of these districts cultivated rubber has been on the market for years. It is stated on good authority that there are cultivated Castilloa trees in Nicaragua over forty-five years old which have been tapped for thirty-five years. A good deal of the rubber planting in Nicaragua resulted in failure and it seems clear from present successes

that only certain parts of the country are suited to the purpose.

Mexican rubber plantations have not proved attractive to the British investor since the collapse of India-rubber (Mexico) Ld.—an English concern—nor can it be said of all the numerous enterprises of this sort which have been started in Mexico that they will bear close inspection. At the same time the cultivation of the Castilloa tree is making good progress, and those concerns whose formation will stand a close scrutiny, should prove profitable investments. The first consignment of plantation rubber was shipped to the United States in 1901, and recent reports point to steady progress. It is impossible to analyse the above table throughout, but a mere glance at it will serve to show that Ceylon and Malaysia have by no means a monopoly of the business.

CHAPTER VI.

INDIA-RUBBER SUBSTITUTES.

Coincident with the establishment of the rubber manufacturing industry has to be noted the efforts of inventors to discover or prepare a substitute. Despite, however, strenuous application to this end it can be said without fear of contradiction that up to the present no real substitute has been discovered. That is if we use the term in its correct sense of substituting rubber entirely. The partial success which has been attained has reference only to the displacement of some part of the rubber in various goods by bodies which reduce the cost at the expense of the quality. Not until we get some substance which, on admixture with rubber cheapens it, without at the same time reducing its quality, can it truthfully be contended that real progress towards the desired end has been attained. The substitutes which have so far been used have really no status beyond that of cheapening ingredients, and it is undeniable that, in the earlier days of the industry, when goods were rarely if ever subjected to chemical analysis, substitutes paraded to a great extent as rubber to the pecuniary advantage of unscrupulous manufacturers. He would be a bold man, however, who contended that such a practice was common to-day. Owing to close competition, those goods in which substitutes are used are sold at their

true value; grasping buyers may possibly be shocked to hear that they are not buying pure rubber, but it is really their own fault. Goods made of the purest rubber can always be obtained from the manufacturers by those who are willing to pay the price, and speaking in a general way of the trade, such goods as are highly compounded are produced often under protest to satisfy the purchaser's ideas as to price. Under these circumstances we join issue with those who refer to the use of substitutes generally as an act of adulteration. It would seem that the cases where this contention would fairly hold are not at all numerous; cases, that is, where goods containing substitutes are sold at the price of pure rubber. Of course there are exceptions to this dictum, but it may nevertheless be taken as generally true.

It would be a vain task to enumerate the heterogeneous list of bodies simple and compound which at one time or another have been confidently proposed as rubber substitutes. The curious on this point will find a good deal to interest them in H. C. Pearson's book. It is sufficient to say that the great bulk of the inventions, so called, have benefited no one except those who are professionally concerned with patents. Invention in this direction, however, shows persistent vitality, and a glance at the patent lists of to-day suggests that practically every known substance is being drawn upon and as often as not for the second time. It hardly seems superfluous to offer a word or two of advice to would-be tillers in this apparently attractive field; firstly, acquaint yourself thoroughly with the physical properties of raw rubber; secondly, get a practical trial of the substance made in a rubber works before spending money on patents.

All this talk about rubber substitutes, notwithstanding, it becomes of interest to consider whether the discovery when made, is likely to be of such supposed value. If there was any real danger of a rubber famine the value of an efficient substitute would undoubtedly be immense. So far, however, from any danger of a famine we can face the future with complacency. As already pointed out in the last chapter, the rubber to be expected in the future from plantations will be produced at about 1*s*. per lb. It will, no doubt, be a long time before the growers sell it at any such figure, but should any threatened opposition arise from a substitute, it may be taken that the growers will forego the bulk of their profits for a time at least, and put good rubber on the market at or about 1*s*. per lb. This means that the substitute, if it is to realise the fortune its introducers will undoubtedly expect, will have to be made at about 6*d*. to 9*d*. per lb. It is difficult to see where the materials are to come from to render manufacture possible at this price, and it is evident that the synthetic rubber prepared by Professor Tilden from terpenes cannot have any commercial significance. It would seem then that, whatever may have been the case in the past, the present prospects of wealth for the discoverer of a rubber substitute are largely illusory. This does not mean that there is no room for improvement in such bodies as are in use at the present time or for the invention of new ones to take their place. Such bodies will continue to offer scope for the inventor, and may be expected to bring him in a fair reward for successful labour. They are not, however, real substitutes, and do not come within the limits of a discussion on rubber substitutes proper. The

main defect in all the bodies which have been used or suggested as substitutes is lack of elasticity. So far the production of this property has quite baffled the investigator, and it follows, therefore, that no substitute has deposed rubber from its high position in cases where elasticity is a requisite. On the other hand, it will be apparent that where elasticity is not really required as in the case of waterproof goods, door mats, etc., substitutes in reasonable proportion may have a legitimate use in reducing cost, without at the same time impairing efficiency to any great extent. Moreover, their use instead of mineral matter enables the specific gravity to be kept low and the suppleness to be maintained.

We may now proceed from the general to the particular and consider the rubber substitutes which are in regular use. These are by no means numerous, in fact, broadly speaking, there are only two which need claim more than passing notice. The first is known in the trade as white substitute, and the other variously as brown, black or French substitute. Exactly when these bodies began to be used in the rubber trade it is not easy to say, but apparently they were known even if they had no regular application long before they attracted the attention of the rubber manufacturer. What is known with certainty, is that forty years ago the white substitute was being made in the neighbourhood of Manchester by two firms, who for many years had a monopoly of the business exporting both to the Continent and to America. In those days the process was more or less a secret one, and no doubt the absence of competition made the business a decidedly profitable one. The case is very different to-day, when a general knowledge

of the reaction involved, has enabled close competition to spring up. Although the actual process of manufacture is a short and simple one and may be carried out successfully, by one possessing no knowledge of chemistry, yet the chemical reactions involved are extremely complicated, and it cannot be said, despite the original work carried out by Ulzer and Horn,[1] and later by Henriques,[2] that we understand clearly all the details of the reactions which take place. It is not proposed here to go into details or to discuss controversial points, and it will suffice to say that the various white substitutes are glycerides, whose fatty acids contain chlorine and sulphur as addition products. The general process of manufacture is to stir a certain quantity of chloride of sulphur—a very penetrating and objectionable liquid—into linseed, rape or other unsaturated fatty oil mixed with petroleum spirit. After a few minutes' stirring, during which time a considerable rise of temperature takes place, the oil begins to thicken and to be converted into a yellowish, more or less elastic body. The particular oil used and the quality and amount of sulphur monochloride added, are matters which affect the final product to some extent. Such details are somewhat jealously guarded by the manufacturers as trade secrets, and there is no intention here to draw aside the veil that hides them from the public eye. With regard to the generalities, however, it may be said that the oil most commonly used at the present time is refined colza, there being a decided difference in the stability of the products obtained from various oils. The presence of free acid was a constant

[1] *Jahresber d. Chem. Technol.*, 1890, p. 1177.
[2] *Chem. Zeit*, 1893, p. 707.

source of trouble to the rubber manufacturers in earlier times, but the substitute makers of to-day have learnt how to produce a neutral product. What is also important is that the liability to decomposition has been greatly lessened. The author can now testify to samples having withstood the action of sunlight for four years without showing signs of decomposition. It used to be the common thing for white substitute exposed in a bottle to sunlight to turn into an oily mass in a few weeks. As an industry, the substitute manufacture has the drawback of being a very disagreeable one for those closely concerned, owing to the fumes of the chloride of sulphur, and many are the stories which could be related of the troubles in which the pioneers of the manufacture found themselves involved. This was owing, it must be confessed, a good deal to the indifference with which they regarded the rights and convenience of their neighbours. As hinted already, the competition of the business is such that the man with ten pounds capital who bought a wooden tub, some oil, and a bottle of chloride of sulphur and set up manufacturing under a railway arch, has been compelled to desist by a concatenation of adverse circumstances. The more substantial firms in whose hands the business now lies, and with whom it forms only a branch of a more general trade, have adopted means whereby the nuisance arising from the fumes has been largely done away with.

Passing on now to the dark or French substitute, it would seem that this was the first in the field. For a long time, certain French firms had a practical monopoly of it as the actual process of manufacture was not understood in other countries. This cannot, however, be said to-day, and

practically all the firms who make the white variety make the dark also with varying degrees of success. The manufacture differs from that of the white substitute, in that sulphur takes the place of the chloride of sulphur, and the reaction takes place at a high temperature. In the process, a vegetable oil is heated to about 200°C., and a certain proportion of flowers of sulphur is added, the mixture being regularly stirred. In due course the oil thickens considerably, and at a certain point it is poured out into a shallow receptacle where it quickly solidifies. Sometimes it is allowed to solidify in the boiling pot, the source of heat being removed. Although apparently a simple process close attention to detail is necessary in order to ensure success and to obtain a uniform product. Though the fumes given off in this case are not so irritating as in the chloride process, being free from mineral acid, yet they are by no means pleasant, as sulphuretted hydrogen is generally present. To some people the vapours of hot oil are decidedly objectionable, and it is not surprising to hear of manufacturers who, after commencing the business, gave it up in order to make a living in pleasanter paths. The brown substitute is a more stable body than the white, and it is somewhat surprising that it has not been used to a greater extent in preference to the latter. No doubt its colour is against it in the case of goods where transparency is desired; but this objection apart, its resistance to decomposition under vulcanizing temperatures makes it the more desirable substance to use for the generality of goods. Some writers have made it appear that the general custom in the rubber manufacture has been to use the dark for steam-cured goods and the white for textures, etc., which

are cold-cured. This, however, has been by no means the case, the white substitute having been used extensively in steam-cured goods. No doubt the hydrochloric acid formed during vulcanization was taken up by metallic oxides or other absorbents present, thus having its tendency to mischief neutralised. All the same there is little that can be urged in favour of the use of white instead of dark substitute in steam-cured goods, and the science which is slowly superseding the empiricism of the past in the rubber manufacture will doubtless cause the use of the white body to be limited to cold-cured goods. The market price of these substitutes varies from 3*d.* to 7*d.* per lb., the lower figure having been rendered possible during recent years by the use of maize oil, which is largely produced in America. A cheapening of the original product has also been effected by the use of "blown oils"—that is, rape or cotton seed oil which has been partially oxidised by air. These latter oils require less chloride of sulphur for their conversion, but the contention made for the product that it is superior to the ordinary substitute, certainly does not meet with general acceptance in the rubber factories.

These substitutes, it should be said, are by no means homogeneous bodies, and a proximate analysis showing oil, sulphur and chlorine has little value. In the ordinary solvents of india-rubber they merely swell up, only a small portion going into solution. They have, however, the special property of going completely into solution when mixed with rubber—that is, as far as rubber can be said to form a solution. Owing to this property, these substitutes have found a large, and it must be added regrettably large, use in the manufacture of cheap

waterproofs, the amount of rubber present being practically limited to the minimum necessary to get the substitute into solution.

Some analytical figures are here appended, giving at a glance the general constitution of these bodies :—

	White Substitute.	Dark Substitute.
Oily matters . . .	88·2	88
Sulphur . . .	6·6	12
Chlorine . . .	5·2	—
	100·0	100

Both substitutes give varying amounts of oily extract to solvents, such as ether and petroleum spirit, and the dark often contains a good deal of its sulphur in the free condition.

The rubber substitutes just referred to represent a class of bodies which are intended for use in the rubber manufacture as a raw material to replace the pure rubber. There remains, however, a class of substances sometimes called rubber substitutes which are complete in themselves, and are made into finished articles to compete with rubber goods on the market. These are either proprietary or patented substances credited, as a rule, with the possession of advantages over rubber, either in the matter of price or of specific attributes, such as the power to resist oil or oxidation. A glance at the history of such bodies in general shows that the failures to come up to expectation largely outnumber the recognised successes, and that there are really very few cases where infancy has evolved into robust adolescence and where longevity can be predicted with confidence. In several cases where a patent was taken out

for a weird-looking mixture of substances said to be capable of replacing rubber, it was found necessary to use a certain amount of rubber as well, in order to produce saleable goods, though the addition was not announced from the house-tops. In other instances, where patented compounds were primarily destined as substitutes for rubber, they have found a wide sphere of utility, not in replacing rubber, but other substances, notably leather. The true leather substitute has not yet been found, and probably never will be, but compounds made from oxidised and nitrated oils have made considerable progress in recent years in replacing leather for certain classes of upholstery work. Thus we have pegamoid, a nitrated cellulose product; pluviusin, an oxidised oil body; velvril, a nitrated oil, and two or three other leather substitutes which have proved their worth for certain purposes. Their claims to be considered rubber substitutes, where they have been advanced, cannot be seriously considered; though, of course, for certain purposes, as, for instance, in belting or bed-sheeting, they may enter into competition with rubber. With regard to viscose, the cellulose product made by Cross and Bevan by the action of carbon bi-sulphide on a solution of wood-pulp in caustic soda, Weber spoke very highly of its possibilities as a rubber substitute. Nothing, however, seems to have come of it, though it had a trial in several rubber factories.

It has already been pointed out that the main defect of so-called rubber substitutes is their lack of elasticity. This remark applies very generally to the bodies we are now considering, and therefore it is not surprising that the greatest success has been scored in cases where elasticity is of little importance, as, for instance, in waterproof clothing

and electric insulation. Thus the diatrine insulation brought out by G. Heyl-Dia, and now the property of Messrs. W. T. Glover and Co., occupies a high place as a substitute for rubber insulation, and much the same thing can be said of the vulcanized bitumen so largely used by Messrs. Callender and Co. as an insulating material. Other bodies largely used for insulating purposes in America are kerite and okonite; the latter, by the way, having been manufactured on a large scale near Manchester a dozen years ago. If, however, we attempt to apply these bodies, so useful in their particular spheres, to the variety of purposes for which rubber is in requisition, their deficiencies as rubber substitutes become at once apparent.[1] An interesting substance, known as vulcanized fibre, has a considerable use for steam purposes, as it is unaffected by the temperatures which would rapidly prove fatal to vulcanized rubber. Another rubber-like compound, which for mechanical purposes has largely replaced both vulcanized rubber and leather, is known as dermatine. This is made by the Dermatine Company of London on the lines of a patent taken out by Zingler in 1884, though it is understood that the original process has been considerably modified as the result of experience. Various gums and chemicals enter into its composition, the product when vulcanized having much the appearance of rubber, though it would seem to have undoubted advantages over the latter for such purposes as hydraulic cup and ram-rings.

[1] As okonite contains rubber it must be excluded from this general observation.

CHAPTER VII.

RECLAIMED RUBBER.

Under the various names of recovered rubber, reclaimed rubber, rubber shoddy, Pongo rubber, etc., rubber goods which have done service in their several spheres of utility again come before the manufacturer's notice. The trade of reclaiming old rubber so as to fit it for re-use has been in existence for a long time; but in recent years it has shown considerable expansion, a fact which may be ascribed to two principal causes: improvement in the methods of production, and the extended market owing to the high price of raw rubber. To effect the devulcanization of old rubber or of vulcanized scrap, a regular product of the rubber factory, is a problem which has long been of the first importance. It cannot, however, be said that we are really in any better position than we were fifty years ago as regards the main object to be achieved. If the term recovery is used as synonymous with devulcanization, it cannot seriously be contended by any rubber reclaimer that the desired goal has been attained. All the brands of reclaimed rubber on the market contain sulphur, and the most that can be said for them is that the original vulcanized rubber, from being an intractable substance, has, by the method of reclaiming employed, been rendered suitable for use again; that is, to a limited extent for certain purposes.

It must not be thought, however, that such reclaimed rubber has anything approaching the characteristics and value of new rubber. This is not at all the case, and there are numbers of goods in which it could not possibly be used with beneficial results. This statement will no doubt be challenged by the reclaimers, or, at any rate, by some of them, but the author derives support from the fact of the general unwillingness there is in the rubber trade to acknowledge the use of reclaimed rubber. This anxiety to avoid publicity can hardly be urged as testimony to its virtues, nor can the clause in the Government specifications, stating that no reclaimed rubber is to be used, be taken in any more favourable light. The use of exaggerated language is perhaps permissible in trade circles, but it does not seem to have been shown that any reclaimed rubber is equal to new rubber of the best quality, though it must be admitted that so great have been the improvements effected by individual firms in recent years, that much reclaimed rubber is produced which is decidedly superior to raw rubber of low grade.

The reclaiming of waste rubber has long been a much more elaborate business in the United States than has been the case in Europe. The principal raw material of the American trade is the discarded golosh—an article which is manufactured and utilised to a much greater extent in America than in England. The collection of the old ones has long been systematised, and quantities find their way to the large reclaiming factories in the States. What the proportion of goloshes collected is to those manufactured is a matter that would probably be difficult to determine, but it is certainly a large proportion. Of course the Americans

use other old rubber stock as well, buying it in large quantities, not only in their own country, but also in Europe. In England and other European countries reclaiming has been carried out on a much more modest scale, and it is only quite recently that the collection of the old rubber goods has been organised into a regular industry. Time was when old rubber could be got by the reclaimer for the asking, or for the trouble of carting it away; but now things are very different, and practically all the waste rubber has to be paid for at full rates. The Government departments—especially the post-office—the railway companies, and other large users now regularly sell their old rubber either by tender or by auction, and smaller users of mechanical rubber goods have recently got into the habit of stipulating with the suppliers that they shall be allowed so much for the old material. In fact, the field is now well covered.

Perhaps the most important fact in connection with the waste rubber industry in Europe is the recent establishment at Litherland, near Liverpool, of a reclaiming factory by Americans. Business is here carried on in a huge factory on American lines, the waste rubber being obtained from Europe generally. It is not surprising that, in mining parlance, the mill at first got ahead of the mine; in other words, that a difficulty was found in getting enough scrap rubber to keep the place in full work. This difficulty, it is understood, has now been overcome. In contradistinction to what obtains in the States goloshes are not the principal raw product at Liverpool, motor and cycle tyres largely taking their place. All classes of rubber goods do not lend themselves with equal facility to the

reclaiming process, and for a long time there was no market at all for goods which contained an excess of canvas or metal. Armoured hose, for instance, has long been looked at askance by reclaimers as involving too much labour in its treatment. With regard to this body it is worthy of mention that a special machine has recently been patented by R. R. Gubbins, by which the metal of internally and externally armoured hose can be expeditiously removed from the rubber at a very trifling cost compared with the hand labour which is generally used. Many rubber goods, notably cycle and motor tyres, contain a considerable proportion of canvas, which has to be removed before the reclaiming process is entered upon. In many cases the separation of the rubber from canvas and metal is carried out by the reclaimers, though there are many waste rubber dealers who carry out this operation themselves, selling the scrap rubber to the reclaimers or to rubber manufacturers direct, many of the latter now having reclaiming plant of their own. As the Gubbins patent machine is now in regular operation, it will be of interest to give a brief description of it. In principle it is a plain and straightforward application of the well-known slitting rolls used in the iron trade for slitting a long sheet of iron into nail rods. The india-rubber tubing or insertion sheet is divided by the action of the rolls into a number of narrow strips almost like belt laces. In this form the fragments of metal are easily removed, and the canvas is quite as readily destroyed by acid or alkaline solvents, as when the rubber has been ground into crumb on rollers after the method usually followed. The construction and working of the machine are characterised by

simplicity, and it should go a long way to render profitable the reclaiming of rubber from armoured hose.

Another patented process for treating waste rubber containing canvas deserves particular mention, as it bids fair to eclipse the older methods in which chemicals are employed. It is due to Penther, a German, though the patent rights for the world have recently passed into the hands of a company, who have put up a factory at Leyland, in Lancashire, to work the process on a large scale. It would be difficult to describe the machine well without diagrams, for which space cannot be afforded, but in principle it consists of a series of knives and air blasts. By the former the rubber is reduced to fragments, and the canvas particles are removed by the air. The canvas now in a state of fluff, quite free from rubber, commands a ready sale for felt making and other purposes, at a price sufficient to pay the running expenses of the machine. In this process then the trouble and expense of the ordinary methods of dissolving the textile material in acid or alkali are obviated, and its success seems assured, though at this early stage of its adoption a little reserve is necessary in casting its horoscope.

The mystery which at one time hedged round the operations of the reclaiming factory has now been largely dispelled, and there exist hardly any secrets in the various processes, except in points of detail. The processes may be roughly classified as mechanical and chemical. In the former case the old rubber is ground on rollers, similar to those already referred to as mixing rollers, to a fine powder, which, after being run over magnets to extract particles of iron, is subjected to a current of air, whereby the particles

of canvas are removed. The rubber is then, according to general American practice, heated in hot air stoves to a high temperature, with the addition of a certain quantity of rosin oil or petroleum, by which treatment it becomes to some extent devulcanized, and capable of being rolled into homogeneous plastic sheets. In its broad outlines this is the process as adopted in the preparation of mechanically reclaimed rubbers. In the chemical or acid process—the patents in connection with which occupied the American Law Courts for so long a few years ago—the fibrous matter is destroyed by mineral acid, sulphuric and hydrochloric being generally used. This form of treatment will be referred to again later. Other and more modern processes comprise a combination of mechanical and chemical treatment. Space does not permit of reference to the varied and very numerous patents which have been taken out in connection with perfecting the reclaiming process, but two systems, from their interesting nature and the large scale on which they are at present being carried on, may conveniently have extended reference. At the works of the North-Western Rubber Company, already referred to as being established at Litherland, near Liverpool, the alkali system patented by A. H. Marks, of the Diamond Rubber Company, Akron, Ohio, U.S.A., is in use. A summary of the process is as follows:—The ground-up waste rubber passes by means of elevators and conveyor belts to a number of oscillating sieves. Here the coarse material is separated from the fine, and goes back to the rollers for re-grinding. The fine material, which has passed the sieves, is taken by a spiral elevator to the devulcanizers, which are large iron vessels steam-jacketed

and capable of standing a high pressure. There are several of these vessels, each of which has a capacity of about two and a half tons of rubber, and in them the most important part of the process takes place. This consists of extraction of the free sulphur with caustic soda solution, and at the same time of the solution of the particles of fibrous matter. When this reaction is over the rubber is thoroughly washed to free it from alkali, and is then dried on specially constructed screens heated by steam coils, a current of air under pressure being used to expedite the removal of moisture. When thoroughly dry it is sheeted on rollers, without it is stated the use of any oil. Of course there are details of importance which this synopsis of the process does not touch, but enough has been said to satisfy the curiosity of the general reader. It is safe to say that had this been a British factory it would not have been possible to say as much. It must not be supposed that the large output of reclaimed rubber from the Litherland Works finds its sole market in England; as a matter of fact, business is done all over Europe, and the site of the factory being where it is is due to considerations of general convenience. We may now pass to the second reclaiming factory it is proposed to refer to, this being one of those rare instances in Europe where the management does not shun a certain amount of publicity. This concern is situated at Copenhagen, and has the euphonious title of Dansk Afvulkaniserings Aktieselskabet, which done into homely English means the Danish Devulcanizing Company, Limited. Here the chemical part of the process is based on the patents taken out by Albert Theilgaard, though the process in its entirety is by no means

revealed in the Patent Office files. The main point to be observed is that neither acid nor alkali is used to effect the solution of the sulphur and fibrous matter, neutral solutions of sulphites being employed as the solvent for the sulphur, while the fibre is removed by certain neutral salts, the exact nature of which is not disclosed by the management. It is stated that the sheeting of the chemically treated rubber is effected without the admixture of any oil or cheap resinous rubber, and if so the process must be considered a highly satisfactory one. The resulting rubber cannot, of course, be either acid or alkaline, and freedom from the oil, which is such a distinctive feature of American practice, naturally brings up the rubber content. In saying this much it must not be supposed that reclaimed rubbers prepared by the other methods are liable to contain acid or alkali. The author's own experience goes to show that, at any rate where reliable firms are concerned, such reclaimed rubbers put on the market are quite neutral as a result of the careful washing process to which they have been subjected prior to sheeting.

Mention has been made of recovery processes in which the fibre has been blown out by an air current, and where it has been dissolved by alkaline solutions. It may also be removed by acids, some reclaimers using a diluted solution of vitriol for this purpose. In this case it is inevitable that a certain quantity of the mineral matter in compounded rubbers should go into solution, but the loss of weight thus caused is not great in practice, because the process is pretty generally confined to cases where the rubber is not ground up, and where the canvas, as in the case of railway-brake hose, has been mostly separated by mechanical means. The chief objection to the acid process is the liability of the

rubber to retain acid in its pores. A thorough washing in water, or better, dilute alkali solution, is necessitated in order to remove the acid. As a rule this work is carried out satisfactorily, and one very rarely hears complaints nowadays of acidity. If prophecy is permissible it would appear that the alkali chemical processes, already referred to in detail, are likely to supplant the acid treatment when the details on which their success depends become more generally known, or when the patents under which they find protection become void by the lapse of time. Where the acid process finds its principal application in England is in the recovery of waterproof cuttings. In proportion to the rubber present the amount of textile material is large, and the process usually adopted with reclaimers is to boil the cuttings—which are largely obtained as waste from the waterproof cutting rooms—in hydrochloric acid solution. The cotton and wool are thoroughly rotted by the acid, and are removed from the rubber by washing on rollers in a stream of water, the washing being continued until the acid is entirely removed. This rubber, especially that from goods which have been cold-cured, is only lightly vulcanized, and fetches a good price. With the decay of the macintosh industry, however, supplies of the cuttings have been difficult to obtain, and the amount of this class of reclaimed rubber has consequently diminished. It may, not unnaturally, be asked whether this process of destroying the textile material is not unnecessary and wasteful. At first sight it may appear so, but it is a fact that of the various patents and processes which had for their object the recovery both of the rubber and the cloth, none, to the best of the author's knowledge, have proved successful. This from a variety of

reasons, some of which may be briefly mentioned. Leaving out of account the diminution in the production of the raw material, we have the important fact that no discrimination is made, either by the waterproof manufacturers or the waste rubber dealers, between the cotton and the wool cuttings. It may be taken that only the latter offer any attraction as far as the recovery of the fabric is concerned, the cotton having practically no market value. If wool or union cuttings could be had in sufficient quantity, and free from those consisting of cotton alone, there seems no reason why some at any rate of the processes which have been proposed should not prove financial successes. The recovered wool has a ready market in the woollen districts of West Yorkshire, though it has to be entirely free from rubber. Among those who have recently worked in this field may be mentioned R. R. Gubbins, in whose patent of 1900 claim is made for the use of hot petroleum oil as a solvent, the softened rubber being squeezed off the cloth during passage through rollers. In the patent of Robinson Brothers and Clift the higher boiling coal-tar bases, obtained as a bye-product in the manufacture of pyridine, are used as the solvent. On heating the cuttings in this liquid the rubber goes completely into solution, and may be precipitated by benzol. The woollen fabric, after washing with sulphuric acid to remove the residue of the solvent, and then in water, is obtained perfectly free from rubber.

To turn to another topic, at one time the old card-clothing used in cotton mills formed a valuable raw material for reclaiming purposes, though the term reclaiming is hardly applicable, the rubber never having been vulcanized. This source of supply has, however, decreased of late years as

not only are the bulk of the rubber-faced cards being vulcanized, but in many cases they have been altogether superseded by the composition cards, which have glue as their basis. One or two other sources of unvulcanized waste rubber are available to the astute collector, but the bulk of such stock is very insignificant compared with the supplies of waste vulcanized rubber. It is upon the latter, and more especially upon goloshes and tyres, that the large factories must depend for their supplies, requiring as they do, not only large quantities of material, but needing it also as far as possible of uniform composition. All the same, compared with what obtained only a few years ago, the organised collection of rubber goods of various classes has grown apace. The erstwhile query as to what becomes of all the pins sold, has not, it is understood, been satisfactorily answered. Any such query with regard to rubber goods has been answered to a great extent in the preceding pages, and if the progress already made continues, there will be few rubber goods indeed which do not find their way back again to the factory after performing useful service outside.

With regard to the extended use of reclaimed rubber at the present day, it has already been attributed largely to the high price of the new rubber. But other considerations have to be taken into account, more especially the improvement in the quality, owing to scientific supervision of the processes of manufacture. Chemical and physical testing forms now an important part of the routine of the reclaiming works, and in ordering certain brands the rubber manufacturer can depend on getting a product which varies in different deliveries no more, or perhaps even less, than does raw rubber of the second or third grade. Further, the

experience of late years has shown that reclaimed rubber can be used with advantage in place of oil substitute, and it would probably be found, if statistics were available, that, allowing for the growth of the rubber industry, the use of substitute in such directions as it was formerly employed has decreased considerably.

It may be contended that this subject has received more attention than it warranted; but as an integral and important branch of the rubber industry it seemed to deserve more notice than other writers have given to it, especially because as a field for the inventor it is clear that its possibilities are not by any means exhausted.

CHAPTER VIII.

THE WASHING OF CRUDE RUBBER.

Having now treated of the natural history and production of the crude rubber, we come to the point at which it enters the factory to be made into the various articles of commerce. The first process it goes through is a thorough washing, in order to remove the impurities referred to in previous chapters. Naturally, some brands require much more cleansing than others, but the machinery employed for the purpose is the same throughout, with the exception of the partial use of the hollander for African brands.

The first process consists in boiling the rubber in water in cast-iron tanks or wooden tubs in order to soften it. After some hours the large pieces are then sliced up with knives, or more often by means of powerful shears, one blade of which is fixed to a wooden stand, the other being operated by the workman. Of late years a few firms have replaced this treatment in the case of dirty African rubbers by the use of a machine called a hollander, in which the slicing up is done by a series of knives working in a tank of hot water. By this means the sand is removed to a greater extent than in the ordinary way of boiling the sliced rubber in hot water. Generally speaking, this constitutes the usual and only process in order to remove as much extraneous matter as possible before the rubber goes through

the washing process proper. The washing mill of to-day is the same in principle as that of fifty years ago, only it is as a rule of greater capacity and heavier build. Essentially it consists of two cast-iron rollers resting horizontally side by side, a common size in present practice being 2 ft. 10in. by 14 in.

The roller may have the surface plain, or it may be grooved with straight, rifle or spiral cuts. Different rubber manufacturers have their own ideas on this point, and rollers cut in a variety of ways are to be met with. The rollers revolve inwardly at different speeds, their distance apart being regulated by screws on the front part of the roller frame. The general arrangement of the machine will be easily understood from the illustration (Fig. 10), and it will be unnecessary to go into details, which are purely mechanical. It may, however, be mentioned that the power required for this work is such that direct driving by means of cog-wheels from the main shaft is now the general rule, and the belt-driven machine that is figured in older books may be considered obsolete.

In the actual washing process the workman places by hand small quantities of the rubber between the rollers on which a stream of cold water is constantly running. The gripping action of the rollers tears the rubber into pieces, the while the stream of water removes the impurities. After passing several times through the rollers the cleansed rubber takes the form of a corrugated sheet containing as impurities hardly a trace of anything except the resins already referred to. These being insoluble in water and of an adhesive nature cannot be removed in this way.

The capacity of the washing machines in general use is

such that one man can wash 600 lbs. of rubber in a day of ten and a half hours. The work is not free from risk, and the accidents which have occasionally occurred in the past have led to the use of certain appliances calculated to protect the workman from the results of any inattention. In Great Britain such safety appliances are not compulsory, but in

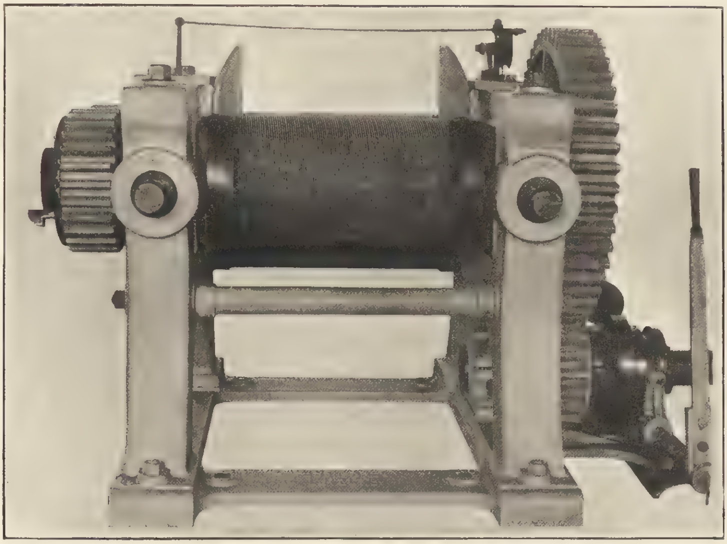

FIG. 10.—WASHING ROLLS.

certain Continental countries, notably Germany, Austria and Belgium, the washing machines and mixing rolls are bound by law to be provided with them. Of late years it has become customary in English works where no special contrivances are used to provide the workman with a wooden pole to push the rubber between the rollers instead of using his hands. The more general tendency, however, is to adopt the instantaneous disengaging gears,

which are now fitted by some, if not all, of the rubber machinery makers at the request of the manufacturer. The details of these contrivances cannot be entered into here, and mention can only be made of that which was designed by Franz Clouth, and which is in regular use in his works at Cologne Nippes. Most of these contrivances take the form of a friction clutch, which cannot be considered the height of perfection for fast-running machinery, and an improvement on this form is seen in Iddon's special instantaneous disengaging gear, which consists of a cam dog clutch. One of the advantages of the electric driving already mentioned as in use at the Leyland and Birmingham Company's works is the facility of stoppage in case of accident. In this works the washing and mixing machines have a patent arrangement like a fire-call in close proximity, and on the glass being broken the machinery is instantly stopped.

Hood, of America, in a patent taken out in 1904, advocates the total immersion of the rollers in water instead of merely allowing a stream to flow over them, and if this can be carried out easily it should lessen the time of washing. It may be taken that the washing process, necessary though it is, certainly destroys the nerve or strength of the rubber to some extent, and this in proportion to the time taken in the operation. Any shortening of this time, therefore, should be advantageous, though it is not possible to say anything with absolute certainty on the point. Granting the truth, however, of what has just been said, it follows that the freer from impurities the rubber is, the less it is likely to lose strength in the washing, and this may be adduced as an additional reason why the collection of the raw rubber should

be carried out as carefully as possible, though it is conceivable that such considerations do not enter very deeply into the mind of the African native.

In the washing department of a large factory it is customary to have the rollers of three different makes, the first, or breakers, being of a stronger build than the others, and having deep spiral cuts on the faces so as to get a good grip of the pieces of rubber. The rough sheet from these rollers passes to others less deeply cut on the surface. The third description of roller to which the sheet now passes has the faces smooth, and can be tightened up so as to produce a very thin sheet in cases where rapidity in drying is aimed at.

Although the two-roll washer is in very general use, three-roll machines were brought out in America some years ago, and are stated to have proved decidedly economical.

Drying of Washed Rubber.

The rubber as it comes from the washing machines has to be entirely freed from water, and this is done by hanging the sheets over wooden bars in large darkened rooms, heated by steam pipes to a temperature not above 110° F. Higher temperatures up to 140° F. are given by some authors, and no doubt a considerable variation would be found if the different manufacturers were to give their working details to the world. In Great Britain steam heating is always employed, though at some Continental works, notably those of the Harburg-Vienna Company at Wimpassing, Austria, the drying is effected by exposure to the air, direct sunlight being excluded. The time taken in the drying-rooms varies from two to six days, or even more, depending principally

upon the thickness to which the sheets of rubber have been rolled on the washing rollers. Although the great bulk of the water is mechanically held on the surface of the rubber, a certain amount is absorbed in its pores, and this is apt to be tenaciously held. For speed of production, therefore, the rolling into thin sheets appears to be the preferable method, except that, for a given weight of rubber, the drying-rooms must be of considerably greater capacity than for the thicker sheet. In cases where floor space is a consideration, what may be generally acknowledged as desirable may not always be found expedient, and the fact that in many factories we find thick sheets being dried must not be taken as an indication that this in itself represents the best mode of procedure in the minds of those who practise it. The suggestion has been made that after drying for a short time the sheets of rubber should be passed through dry rollers to squeeze out the water of absorption, and there seems little doubt that this procedure would expedite the drying. Although the use of Blackman propeller fans has been adopted to some extent for the purpose of removing the moisture-laden air from the drying-rooms, it is quite a modern practice, and its advantages do not seem to be so obvious as might be supposed. Just at first, when the superficial water is being removed, they certainly act beneficially, but afterwards, when the amount of water given off per hour is comparatively small, they are of very little assistance; moreover, by bringing in external air, which has to be heated, there is an increased fuel consumption. Again, unless means are provided whereby the incoming air may circulate throughout the room, it will not do much good, as it will go straight from the inlet to the propeller. The

arrangement of air passages means the blocking up of the interior, thus making the task of the workman more difficult. Quite possibly others have had a different experience in this matter, and in stating his own the author has been actuated more by a desire to call general attention to an interesting subject than to any disposition to speak authoritatively. The topic, although as old as the trade itself, has not had that attention paid to its scientific principles as it would seem to warrant, and the discussion which has recently taken place in the pages of the *Gummi Zeitung* is to be welcomed as likely to lead to improvement and economy in the future.

It has been said that the sheets of wet rubber are hung up in the drying-rooms, but this statement must be qualified by the remark that this system is not applicable where the rubber contains a considerable quantity of resin of low melting point. Sheets of this composition, if hung up, would be soon found on the floor, so they have to be laid out on trays or shelves together with certain qualities which do not sheet well, and so have to be dried in pieces.

Drying in Vacuum Apparatus.—Some fifteen years ago, it was suggested that the wet rubber might be more expeditiously and cheaply dried in vacuum chambers than by the ordinary process just described, and machinery to this end was introduced by Passburg of Berlin. It was further claimed for this process that it entirely prevented the superficial oxidation of the rubber, which took place during drying at elevated temperatures. The latter point is a scientific and somewhat controversial one, the discussion of which would be outside the scope of the present work. With regard, however, to the subject generally it must

be said that, while vacuum drying has been adopted in many large rubber factories, its progress, in recent years, has been by no means rapid, and there is a disposition among some of those who praised its advent to secede from their allegiance. This must not be taken to mean that the vacuum plants—and there are now several types emanating from different makers—do not do all that is claimed for them. The question seems to be primarily one of first cost, though it must not be overlooked that the dehydration is performed in a much shorter time than in the ordinary process. The differences of opinion which have arisen with regard to the vacuum process are, no doubt, due to the variable composition of the rubbers experimented with, and it may easily be that it presents decided advantages in the case of some brands of rubber, and practically none in the case of others.

For the subsequent processes of the manufacture it is important that the rubber be quite dry; "bone-dry" is the common expression for what is desired and aimed at. It is doubtful, however, if much of the rubber used is actually free from moisture. It is not so very uncommon to find quite a half per cent. of moisture in resinous rubbers, and it depends on the purpose to which the rubber is put whether any damage ensues. Generally speaking, ·25 per cent. should mark the maximum of water present, and there is no difficulty in getting it down to this figure, which may be considered low enough to preclude any subsequent damage resulting from "blowing."

CHAPTER IX.

THE COMPOUNDING OF INDIA-RUBBER.

Owing to its elastic nature india-rubber lends itself with great facility to admixture with a variety of substances both organic and inorganic, and the preparation of rubber compounded with mineral matters forms a large part of the factory routine, and, indeed, in many works none but such compounded goods are turned out. Although in a good many cases the main reason for such compounding is the desire to reduce the price of the goods, yet this is by no means the only reason, and the admixture of cheap mineral matter with the rubber cannot, therefore, correctly be described as adulteration. There are many classes of goods where the use of rubber alone would be not only wasteful, but positively disadvantageous, and in such cases the mineral constituents confer decided benefits over and above their effect in reducing the price to the buyer. Having said thus much it must, however, be added in the interests of truth that the capacity of the rubber for taking up mineral matter has been utilised in many cases to a far greater extent than can be considered expedient either in the interests of the purchaser or for the welfare of the trade. Where the difference in price between the rubber and the mineral is so great, it is not surprising that close

competition has led to the increasing employment of mineral, an extra 1 or 2 per cent. meaning a reduction in cost which will easily enable one manufacturer to gain business at the expense of rivals who have not gone quite so far in compounding. To such an extent indeed has this practice gone that goods are to be met with in which the rubber is infinitesimal rather than plenary as in past times. It has been suggested that the answer to the query what is rubber may be expressed as follows: "Rubber is an elastic material used for binding together chalk and other minerals in the manufacture of certain goods." The reader will see in the chapters on cut sheet and elastic thread that this answer is certainly not universally true, but it cannot be contended that it has no application at all to the trade. One effect of over-compounding has been to excite mistrust as to the suitability of rubber for certain purposes, but when engineers talk about rubber being rubbish, they should see to it that they ask a reputable house for a good quality, and they will perhaps change their opinion. Of course, a good quality will cost more than inferior stuff, and some pains should be taken to discriminate between goods offered at different prices. Considerable injustice has been done in the past to manufacturers of the front rank by reason of their goods having been compared by purchasers to others of apparently equal quality sold at a considerably lower price, and the same thing is no doubt existent to-day. The accusation levelled at the former as to making exorbitant profits has, in the majority of cases, been entirely unjustified, a fact which would speedily reveal itself to the purchaser if he made careful comparisons of the behaviour of the goods in practice.

But not to pursue this somewhat worn, though important topic further, we may proceed to the consideration of the more important chemicals and minerals used in compounding.

In pursuance of a custom originating in the early days of the industry, it is usual to refer to the various chemicals and minerals as drugs and to their habitat in the factory as the drug-room. This nomenclature seems objectionable, though it has sanction in the common use of chemist and druggist as applied to individuals. On the Continent the chemist is always distinguished from the druggist, and the dealings of the latter being associated entirely with medicine, it seems inadvisable to introduce the name into manufacturing operations which are not concerned, except in a very indirect manner, with medical matters. Certainly the term "drug" is shorter than "chemical and mineral," but the latter will be used in this volume.

To merely enumerate the various bodies which have been advocated by inventors as ideal components of rubber goods would encumber more space than would be justifiable. The group of substances would be seen to be of an extremely heterogeneous nature, including powdered coal, oxide of gold, Fuller's earth, and whalebone. In the majority of cases the substances commonly used are chosen more from their physical attributes of weight, colour, etc., than by reason of their chemical composition, and in only very few cases does any chemical reaction result. The following table gives the chemicals in common use, though no doubt the list might be augmented were the practice of individual manufacturers made public.

Inorganic Compounding Materials.	Specific Gravity.
Antimony pentasulphide	4·6
Asbestos powder	2·6
Barytes	4·5
French chalk	2·7
Magnesium carbonate	2·2
Magnesia	3·4
Lime	3·0
Lampblack	·2
Litharge	9·3
Lithopone	3·6
Plumbago	2·0
Red oxide of iron	2·0
Silica	1·8
Sulphur	2·1
Vermilion	8·1
Whiting	2·8
White lead	6·2
Zinc oxide	5·6
Zinc sulphide	5·8

In addition to the above, there are various proprietary articles sold under special names. In these days of chemical analysis such articles are not in so much request as in former times, when the supposed merits of such ordinary bodies as whiting or red oxide of iron, sold under fancy names at enhanced prices, were accepted in blind faith without their claims to notice being subjected to rigid examination. As colouring matters, besides the antimony, lampblack, red oxide and vermilion mentioned above, indigo, ultramarine, green oxide of chromium, cadmium sulphide (yellow), arsenic sulphide (yellow), and various lakes derived

from coal tar colours have been used. Colouring matters capable of withstanding the processes of vulcanization are not too readily found. Especially is this the case with yellows—chromate of lead loses its colour under the influence of sulphur and heat; cadmium sulphide is expensive, while the poisonous nature of arsenic sulphide is a decided bar to its use. With regard to the toxic properties of the colouring matters used in the trade, the subject only becomes of any real importance in connection with india-rubber toys, a topic which comes up for treatment in another chapter.

Any enumeration of the properties of the above list of substances would be a matter of pure chemistry, and appears to be uncalled for in this volume. The few observations which it is proposed to make will be concerned, therefore, with the main reasons for their employment as indicated in their specific composition and properties.

Red or golden *sulphide of antimony* has a large application in the manufacture of red rubber goods, nothing having been found to take its place. At one time it was looked upon as a vulcanizing agent able to replace sulphur, but its action in this respect was due very largely, if not entirely, to the free sulphur it contained. This sulphur may amount to as much as 25 per cent., and is rarely below 15 per cent. In some brands a considerable proportion of hydrated sulphate of lime is also present, resulting from the method of manufacture adopted. In practice it is important to know the amount of free sulphur present in order to regulate the extra amount which it is generally necessary to add to effect a proper vulcanization.

Although usually of an orange-red colour, it is made of varying shades, an almost crimson tint being in demand for certain purposes.

Asbestos powder and fine fibre find application in certain mechanical goods, such as packings and valves intended for heat resisting purposes. In the powdered form it is practically the same thing as French chalk, being very similar in chemical composition.

Barytes is used in the form of the sulphate (and not as the more expensive carbonate) merely as a weighting material. It is quite unaffected by heat, sulphur, or dilute acids, and is never adulterated itself, though it is largely met with in the cheaper brands of white lead offered to the rubber manufacturer. The price is regulated by the fineness and colour, special qualities being sold under the names of "permanent white" and "blanc fixe."

French chalk, which is a natural silicate of magnesia, and is also known as talc, is used to some extent in compound rubbers, especially in those for electrical purposes, but it is used to a much larger degree in the factory as a means of preventing adhesiveness in unvulcanized rubber. A little of the powder dusted over the surface performs this object admirably, and many goods are vulcanized in trays containing a bed of the material.

Magnesia is used to some extent in the form of the oxide or calcined magnesia, though, at the present day, to a much greater extent in England as the hydrated carbonate. This is an extremely light flocculent body, consisting chemically of the carbonate mixed with a certain proportion of the hydrate, and having a decided alkaline reaction. Its composition is somewhat variable, depending upon the

process of manufacture, and it may be expected that the product of different makers, even if of the same degree of purity, will give varying results in practice. The extreme lightness of the material is due to the retention of air by the particles, the actual specific gravity when it is mixed with the rubber being about 2·2. It seems advisable to mention this point because some very erroneous views are current with regard to it. The use of magnesium carbonate has increased to a very large extent in late years, although it is decidedly more expensive than many other mineral substances used in the trade. It possesses, however, the properties of lightness and of giving toughness to soft or resinous rubber, to mention only two of its advantages over cheaper bodies, and the general, though somewhat tardy, recognition of its merits has led to a greatly increased demand. Goods in which it has been largely used are solid cab tyres, which, in their perfection, combine comparative lightness with resiliency and strength. Carbonate of magnesia should be stored in a dry place, as it is apt to absorb hygroscopic moisture in excess of that normally combined. Oxide of magnesium, made by calcination of the carbonate, is used in small quantities as a moisture absorbing and hardening agent, finding its principal application in the vulcanite manufacture, though of late, especially in Germany, it has been used in tyres and many other goods to facilitate vulcanization.

Lime, in the form of specially prepared hydrate, is used in small quantities only as an aid in the vulcanization of soft rubbers. Theoretically, the pure oxide, or quicklime, should be more useful than the hydrate, but in practice the latter is nearly always used, as it answers the purpose

intended, and its employment is unattended with the risks attaching to quicklime.

Lampblack is a common name for the more or less carbonaceous material serving for the production of black rubber goods. Blacks are sold under various names which may, or may not, have anything to do with their origin. Thus we have lampblack, vegetable black, gas black, etc. This may be unsatisfactory from a scientific standpoint, but, in the trade, blacks are purchased on their intrinsic merits without any particular regard being paid to the name they bear. At the present time light carbon black of good covering capacity is obtainable at a much cheaper rate than ten or fifteen years ago, being prepared by the imperfect combustion of the natural gas exuding from the ground at certain spots in the United States. If this source should give out, a by no means improbable eventuality, we may expect carbon blacks to revert to something like their former price. Adulterated blacks are now rarely, if ever, met with, the density, colouring power, and presence of oily constituents being the main points which claim the buyer's attention. Besides being put into the body of the rubber, lampblack is used in making varnish for rubber boots and shoes, black surface macintosh cloth, and other purposes. In a general way the value of a black is directly in proportion to its colouring power, though there are cases when the presence of an inert mineral substance in a low quality brand comes in useful as a filler. An objection, however, to the use of these common blacks is that the manufacturer does not know exactly what he is using, a point on which it is desirable that he should always possess complete knowledge.

Litharge occupies the double *rôle* of weighting material and sulphur carrier in the vulcanization process, and in the case of dark coloured goods its use is very general. Of late years it has almost entirely replaced the red lead and white lead of earlier times; the use of these bodies, more particularly of red lead, never having been satisfactorily justified on scientific grounds, to the best of the author's knowledge. In place of the ordinary white lead prepared by the old Dutch process, the sublimed lead, which is mostly a sulphate, but containing a little oxide, has been largely used of late years in rubber factories. Although this was made for some years by the White Lead Company, Ltd., of Possilpark, Glasgow, by Hannay's patent, the manufacture was subsequently abandoned. A similar product, however, is now being made in New Jersey, U.S.A., by the "Pitcher" process. In these processes the white lead, instead of being made from the metal, is produced directly from galena, the sulphide ore, by roasting it in a current of air at a high temperature, the sulphide being oxidised and sublimed as sulphate. This form of white lead, being practically non-poisonous, has advantages over the ordinary carbonate of lead in many of its applications. All these lead compounds combine with sulphur at the vulcanizing temperature to form black sulphide of lead, a fact which goes a long way to explain the non-blooming of goods in which they are used. As copper is found occasionally as an impurity in litharge it should be tested for, otherwise adulteration need not be apprehended. Besides being directly obtained from the oxidation of lead, litharge in fine powder is got as a bye-product in the sodium nitrite manufacture, and in Parkes' desilverization process.

Lithopone is a name given to a chemically prepared mixture of zinc sulphide and barium sulphate, it being sold at different prices, according to the proportion of zinc sulphide present. Orr's zinc white, and Griffith's zinc white, are products of the same character. They are of comparatively modern introduction, and their use in place of zinc oxide in the rubber trade, though pretty general, is by no means universal. Their substitution for zinc oxide certainly constitutes an economy, but a difference of opinion exists among manufacturers as to how far such substitution is generally advisable.

Red oxide of iron is largely used as a weighting and colouring ingredient for the cheaper classes of goods, where the use of antimony sulphide is precluded from considerations of cost. The chief thing about this chemical which worries the rubber manufacturer is the large number of almost indistinguishable tints in which it is sold. If he asks for a sample the dealer sends him two dozen small packets of varying shades and prices ranging from 6*s*. to 40*s*. per cwt., and the odds are that unless a careful examination into the whole matter is made, the wrong substance will be bought. It depends entirely on the particular goods to be made whether a cheap or an expensive oxide should be bought. The main point to remember, however, is that the price corresponds, or should correspond, to the depth of colouring power obtainable, this being determined quantitatively, as in the case of lampblacks, by mixing a certain quantity with white lead and a few drops of linseed oil on a porcelain tablet, and comparing the tints obtained. Venetian red, Persian red, etc., are names under which red oxides of a greater or less degree of purity are sold. While the best

product results from the calcination of sulphate of iron, the commoner ones are merely the ochres dug out of the ground, and, in some cases, used as iron ores.

Plumbago, or graphite, finds its principal application in the preparation of heat and oil-resisting rubber, and does not call for any particular mention.

Silica has been largely recommended as a filling material for rubber, but its use has never been extensive. It is in the extremely light form of diatomaceous earth, or kiesulguhr, that it has been repeatedly put before the rubber manufacturer's notice, but the advantages said to accrue from its use are by no means generally testified to in the trade. This may, of course, be due to a lamentable want of discrimination on the part of the manufacturers; sellers of rubber chemicals frequently having to complain of the Laodicean attitude adopted by manufacturers towards new and important products brought to their notice. This body consists of the skeletons of minute infusoria, and is found at the bottom of inland lakes in Nova Scotia, Germany and Sweden, a deposit also occurring near Belfast, in Ireland. According to Pearson, it is used in small quantities in America, in various rubber compounds in which it increases both strength and resiliency, though if used in excess it makes a very hard compound; a special instance given of its use being the Jenkins elastic valve packing. In the form of fine sea sand silica is used in ink-erasing rubbers.

Sulphur is used as a vulcanizing agent in the three forms of brimstone, flowers of sulphur, and precipitated sulphur. The use of roll brimstone is limited to the sulphur bath, though in the finely powdered form it sometimes takes the

place of flowers of sulphur in the ordinary vulcanization process. Probably 90 per cent. of the sulphur used is in the form of flowers of sulphur, of which there are several brands on the market specially prepared for the rubber trade. It would be somewhat invidious to go into details concerning the merits of the respective brands, and it will suffice to say that the essential points of a good sulphur are fineness of subdivision, *i.e.*, freedom from grit and crystals; and neutrality, *i.e.*, absence of sulphur acids; and where manufacturers have a comparatively cheap sulphur offered to them they should satisfy themselves that crystals and acid are absent. Different brands of flowers of sulphur, although they may all test 99 per cent. purity, may vary considerably in their physical characteristics. Although the specific gravity of sulphur is 2, different lots show considerable variation in the space they occupy weight for weight; thus when lightly packed in casks of a particular size one brand may weigh a hundredweight and another not more than three-quarters of a hundredweight. In some factories considerable importance is attached to this point, though there really seems to be nothing in it, the distinction vanishing once the sulphur is thoroughly mixed with the rubber. Again considerable difference in colour is noticeable in brands of equal purity, and any variation in the tint of deliveries is regarded with suspicion at the factory. In this particular, apprehension is not entirely groundless, because the colour is to some extent a guide to the source of origin, though not necessarily an indication of purity. In a general way a bright lemon colour shows the finer qualities of sublimed flowers of sulphur, while the paler tints indicate a lower quality, or it may be powdered brimstone. As regards

acidity, however, the deeper the yellow colour the higher the acid, may be taken as axiomatic. Up to quite recently Sicily has practically supplied the world's needs of sulphur; now, however, in addition to the recovered sulphur of the alkali trade, and the output from Japan, the utilisation of the deep sulphur deposits in Louisiana has struck a decisive blow at Italian supremacy, though it is to be expected that a working arrangement as to prices will be come to.

The third kind of sulphur to be mentioned has never had more than a limited application, and this to some extent because of its higher price, and also because its application has not been generally studied or understood. Known variously as precipitated, block, or metallic sulphur it occurs as a white, finely-divided powder, obtained by the decomposition of an alkaline sulphide or sulphydrate by acid. Most of what was formerly used contained about 25 per cent. of sulphate of lime, precipitated in conjunction with the sulphur. This constituent must be considered as undesirable; but as supplied in recent years by one firm, at any rate, it has tested 99 per cent. sulphur. Owing to its extremely finely-divided condition it can enter into intimate combination with the rubber, allowing of a less proportion being used than in the case of ordinary flowers of sulphur. With regard to its supposed non-blooming properties further confirmation is needed.

Whiting, which is ordinary chalk purified by levigation, has considerable application as a cheap filler in rubber goods.

Zinc oxide is perhaps the most important weighting material added to rubber goods. Besides giving a white colour, it confers upon the rubber properties with regard to many of its applications which are not possessed by pure

rubber. Thus its addition to rubber goods must in no wise be looked upon as an adulteration or merely as a cheapening device, a statement which finds support, if such is needed, in the terms of the Admiralty specifications enjoining the use of certain quantities of the material. The presence of even traces of lead compounds spoils the colour of the rubber goods, so the zinc oxide generally used is that which is prepared by burning the metal in a current of air. The products of various chemical precipitation processes never seem to have met with favourable consideration in the rubber factories. In America, however, large quantities of zinc oxide are prepared direct from a complex carbonate of zinc ore, and the product appears to give entire satisfaction in the American rubber trade, where conservatism is not so rampant as on this side. The American manufacturer is said to examine a substance because it is something new, while the Britisher leaves it severely alone for the same reason. This savours somewhat of exaggeration, no doubt, but at the same time it is not without an element of truth. At the time of writing zinc, like all other metals, is at a high price ; but as regards the future, now that the problem of satisfactorily treating the immense quantities of low-grade complex ores which occur in Australia and other countries has been solved, it must of necessity result that the price will fall considerably before long—that is, in the absence of any gigantic trust. But, not to diverge into purely metallurgical matters, a word may be said as to calamine. This body is frequently referred to in formulæ for rubber mixings, but it has a certain amount of mystery connected with it which the author has never completely penetrated. Calamine is the mineralogical name for carbonate of zinc, but as met

with in the purlieus of the rubber factory, it used to consist largely of whiting. Pearson's statement that the use of a little calamine hardens the rubber is interesting. Of late years pure calamine, as precipitated from a soluble zinc salt by sodium carbonate, has had an extended trial as a substitute for zinc oxide, but it is understood that it has not proved satisfactory as a substitute for the oxide. *Sulphide of zinc* finds regular application where its covering capacity and the smooth surfaces it produces in the case of single textures are considered as compensating for its price. It is also employed in the dental rubber branch.

CHAPTER X.

INDIA-RUBBER SOLVENTS AND THEIR RECOVERY.

Although india-rubber is soluble in many liquids, as far as manufacturing operations on the large scale are concerned there are only three solvents which call for mention. These are coal-tar naphtha, petroleum spirit or benzine, and shale naphtha. The first is used to the largest extent, as it is undoubtedly the best solvent. Its composition is by no means uniform, being made up of benzene, toluene, and xylene in proportions determined, as a rule, by the market prices of the various coal-tar products. The original solvent naphtha consisted chiefly of xylene with but small amounts of the lower boiling homologues, toluene and benzene. At the present day it may, or may not, consist of xylene, but except that increased volatility results from an admixture of lower boiling homologues, there is nothing to be said against them, the solvent power in each case being for practical purposes identical. Indeed, when 90 per cent. benzol is cheap and solvent naphtha is dear it would pay the manufacturer in many cases to buy the former instead of the latter. During the last few years, owing to a decreased demand, solvent naphtha has been remarkably cheap; while in the winter months the increased use of benzol in the manufacture of carburetted coal-gas has caused appreciation in its price. Such fluctuations in the

relative values of these coal-tar products will continually arise, though in the absence of any great revival in the proofing trade there seems little probability of solvent naphtha rising again to prices which ruled some ten or fifteen years ago. It is bound to form one of the intermediate products in the distillation of tar for carbolic acid, anthracene, and pitch, whilst, unlike benzol, which is in large request in the coal-tar colour industry, solvent naphtha has a very limited market outside the rubber manufacture. The ordinary contract form for solvent naphtha specifies that 90 per cent. must distil over at 160° C.; in some cases 95 per cent. at 165° C. is stipulated for. The specific gravity varies from ·865 to ·880, though, as this affords no clue to its real constitution, its determination, at one time looked upon as an important matter in the rubber factory, may as well be ignored. Freedom from heavy oil is an important matter, though this impurity is but rarely met with nowadays. Small quantities of naphthalene, carbon bi-sulphide, and pyridine are common constituents, though rarely in amounts sufficient to warrant any notice being taken of them. Their objectionableness lies not in any injurious action on the rubber, but in the effect they have on the workpeople exposed to the naphtha fumes. In a general way it may be said that a solvent distilling within a range of 40° C., say from 110° C. to 150° C., is best suited for the manufacture of proofed cloth, though for quick-drying solutions benzol, which distils within a range of 20° C. and boils at 81° C., is preferable.

Petroleum spirit as a solvent for india-rubber has been used much more extensively on the Continent than in

England, mainly from considerations of price. As a solvent it is decidedly inferior to solvent naphtha, and, indeed, it would have very little application at all unless it were admixed with a certain proportion of the latter. At the present time, as the price of benzol has fallen on the Continent, owing to its increased production as a bye-product in recovery coke ovens, the use of petroleum spirit or benzine in the rubber trade has decreased. Of somewhat variable character, the petroleum spirit shows an even wider range of boiling points than solvent naphtha, though samples ranging from 30° C. to 160° C. are not to be recommended. If only for considerations of fire risk, it is inadvisable to employ a product which commences to distil below 55° C. Such spirit, it may be said, is an after product of the light petrol now so largely used by motorists, and the associated dangers of which are matters of general knowledge. While solvent naphtha consists of the aromatic series of hydrocarbons and petroleum spirit of the paraffin series, the third solvent we have to consider consists of the olefine series. Known commonly as shale naphtha, or spirit, it is a product of the shale distillation industry, which is so largely carried on in Linlithgowshire and Midlothian. Although a fairly good solvent for rubber, certainly superior to petroleum spirit in this respect, its characteristic penetrating smell has always been against its more general adoption, even when the price offered decided allurements. Although not unknown in English rubber factories, it is in Scotland where it has been mostly used. With regard to its composition, it should be said that it is now produced of much superior quality to what was usually the case twenty years ago. Not only is there a complete absence of the high-

boiling, oily constituents which used to be such a menace to its use in waterproofing, but its deodorization has been effected with a considerable degree of success. Its initial boiling point has also been raised in the qualities expressly intended for rubber works, 80° C. to 150° C. constituting now the ordinary range of distillation.

The following table gives the distillation figures yielded by solvents tested by the author :—

DESCRIPTION OF SOLVENT.

	Solvent Naphtha.	Solvent Naphtha.	Shale Spirit.	Petroleum Spirit.
Specific gravity at 15·5°C .	870	875	830	720
Boiling point . . .	110°C.	116°C.	70°C.	38°C.
10 per cent. . . .	121	129	91	65
20 ,, . . .	124	133	98	71
30 ,, . . .	125	137	104	76
40 ,, . . .	128	141	111	81
50 ,, . . .	132	144	118	85
60 ,, . . .	135	146	126	91
70 ,, . . .	138	148	132	97
80 ,, . . .	141	151	140	105
90 ,, . . .	147	156	153	121
95 ,, . . .	155	161	158	143

The Recovery of Naphtha.—The great bulk of the solvent naphtha used in rubber factories, and all of that employed in card cloth works, is used in connection with "spreading," and after it has served its purpose it is dissipated by heat. Not unnaturally, the idea of recovering it for use over again has attracted a good deal of attention, and at one time or another various arrangements have been devised whereby this could be effected. It would occupy too much space to follow the history of this interesting subject from its birth to its present stage of development, though a synopsis of its

main features may be given. Speaking generally, as regards the waterproofing trade, at the height of its prosperity, only one or two recovery plants have been in regular operation. In many cases money has been lost by the erection of plant by engineers who had no close knowledge of the properties of the solvent they were dealing with, and in other cases plant which under favourable conditions would have worked as well on the large scale as in the laboratory model proved ineffective under the factory conditions involved. It is one thing to condense hydrocarbon vapours as obtained pure from the heated liquid, and quite another to condense them on the large scale when admixed with air. Whatever means of condensation have been suggested, the collection of the vapours from the spreading machines has been the same in principle in all cases—namely, the employment of a close-fitting hood, usually of galvanized sheet iron. It is imperative, however, that a certain amount of air gets mixed with the naphtha vapours, thus complicating the ensuing condensation. The amount of admixed air will, of course, depend upon the number of times the workman opens the door of the collecting hood in order to examine the work in progress, and also, to a great extent, upon the regularity of the work. Intermittent working, which is by no means uncommon in the proofing branch, is all against economical results being obtained in the recovery process, as is also the separation of the spreading machines in a number of small rooms, instead of having them all concentrated in one compartment. Various other causes might be cited which have conduced to the unsatisfactory working of recovery plant in rubber factories in the past. With regard to more recent years, the decline of business and the

reduction in the price of the solvent have operated against the erection of new recovery plant. If we turn, however, to the card cloth industry, of which more is said in another chapter, we find the recovery of naphtha the rule rather than the exception. The general conditions of work are here more favourable than in the case of the waterproof clothing manufacture. The rubber to be spread is always of the same composition, with the same weight of naphtha, and there is no such necessity for the workmen to open the lid of the hood to look for or adjust any incidental defects as the work progresses. Recovery plants have been in regular operation in Lancashire and Yorkshire for many years with an average recovery of 75 per cent. of the naphtha used. In these recovery plants, as made by Siddeley and Co., of Liverpool, the naphtha vapours are drawn from the hoods and condensed in metal tubes cooled down below zero by an ammonia refrigerating machine. The condensed naphtha in the older plants is rarely quite pure enough to be used again as it is, and is usually returned to the distillers for redistillation in order to free it from oil derived from the condensing machinery. In the more recent plants erected by the same firm oil lubrication is done away with, and there is no need to redistil the naphtha. Thus, whatever the rubber manufacturer may have to say on the subject as the result of his own experience or non-experience, it is a fact that the recovery of naphtha from spreading machines is not only perfectly feasible, but is also, under favourable circumstances, attended with marked economical results. In saying this it should not perhaps be overlooked that when the majority of these recovery plants were put down the comparatively high price

of the solvent held out an inducement for the expenditure of capital which might not have been considered justifiable when prices fell. However, even with naphtha at 6*d*. per gallon, the recovery plants were all, to the best of the author's knowledge, kept in operation, a fact which testifies abundantly to their economy. With regard to this point of economy, it should be pointed out that the advantages accruing to recovery are not all comprised in the cash value of the naphtha recovered. The purification of the air of the spreading-room is of no small moment, as it makes the work much more agreeable to the operatives, and also reduces the danger of fire to a minimum.

CHAPTER XI.

INDIA-RUBBER SOLUTION.

This product, which has become of such great familiarity since the rise of the bicycle, is made both at the rubber works and also to a large extent by cycle agents and other retailers, who buy the masticated rubber from the factory. This wider dissemination of the trade had its origin no doubt to some extent in the desire to save intermediate profits, but it is also largely attributable to the somewhat onerous restrictions placed upon the transit of the solution by railway and steamship companies. Very little solvent, as ordinarily employed, has a flash point over 73° F., and thus the solution made from it has to be dispatched under specified conditions and at special rates. One can hardly blame the carrying companies for safe-guarding their interests, though too much has been made of the so-called explosive nature of the solution. Even if a light should be applied to a vessel of it, it will merely flare up and soon burn out, and explosive effects can only be experienced when the vapours from uncovered vessels evaporate into the air of a closed room. In such cases the explosive mixture will detonate with probably disastrous results to the immediate vicinity if a light is brought into contact with it. Seeing that these facts, simple though they are, appear to be as yet imperfectly understood by many of those who store and deal in rubber solution, it can hardly be contended that the regulations attending its storage enforced by the London

County Council and municipal bodies throughout the country are too stringent. With regard to the flash point of the solvents, it has been largely supposed that ordinary solvent naphtha does not come within the 73° F. limit, but between this and the 120° F. limit. Careful determinations, however, which the author has made with a Board of Trade standard apparatus, show that ordinary solvent naphtha with an initial boiling point below 100° C. very frequently flashes about 71° F. With regard to solution made with petroleum and shale spirits, it may be taken that it will always come within the 73° F. limit. In cases where it is important that the solution shall be well above the 73° F. limit, it is necessary to use the regular solvent naphtha, consisting of xylenes and a little toluene, but practically free from benzene or the light products of Scotch cannel coal; such naphtha, which does not boil below 125° C. has a flash point about 85° F. In making the solution it is not sufficient to merely add the rubber to the naphtha. In order to get a uniform product the two must be churned together for some time. This treatment is necessary to break down, so to speak, the insoluble or fibrous constituent already mentioned as being a component part of rubber, otherwise only the soluble portion would be in solution and the fibrous constituent merely swell up. Various machines are in use for solution making, some form of pug-mill with a tightly fitting lid being the most common. With regard to the strength of the solution this varies according to price and specific requirements. The British War Office, which uses a good deal in the Carriage Department at Woolwich, stipulates for 18 per cent. of rubber, and this may be taken as the highest strength which can conveniently be obtained

and satisfactorily employed. In other cases, where it is used in the cycle and motor repairing business or in the hat trade, it is generally weaker in rubber, 9 to 15 per cent. being limits within which it is commonly sold. Although at one time Para rubber was exclusively, or, at any rate, very generally, used for solution making, at the present time lower grades find considerable employment. The item of cost has doubtless a good deal to do with this, but it must not be considered as the exclusive reason for the change of procedure. For some purposes a stickier and slower drying solution is preferred, and in this case the cheaper resinous African rubbers do as well as fine Para, and with a decided saving of cost—to the manufacturer at all events. But the substitution of lower grades of rubber for the best does not measure the whole change which has taken place from former practice. A weak solution has been strengthened by the addition of foreign bodies, among which may be mentioned common rosin, a practice of which it is difficult to say anything favourable. Another departure which we seem to owe to America is the compounded solution sold for solutioning fabric intended for motor tyre repairing purposes. The budding trade in this seems, however, to have been arrested at an early stage by the buyers getting an expert to tell them the composition of the solution and then promptly making it for themselves. Rubber solution can be made with other solvents than naphtha and petroleum spirit, but there are objections to their use, except on a very small scale, for special purposes.[1] In the

[1] Quite recently carbon tetrachloride has been used on the large scale for making solution.

case of a certain proprietary article for tyre mending the rubber is dissolved in bi-sulphide of carbon, a liquid which ought to be barred in this connection, in the author's opinion, by reason of its toxic and inflammable nature. Quite recently a rubber solution, said to be non-inflammable, has been put on the market, and if its claims in this respect are found to be substantiated it will certainly be welcomed by the retailer who goes in constant fear of contravening the Petroleum Acts, or of having his insurance premium raised. An interesting development of the solution industry is the recent attempt to use vulcanized rubber. The principal drawback appears to lie in the necessary use of heat in order to get the rubber into solution. This effects a partial decomposition of the rubber and causes the solution to dry very slowly, sometimes indeed taking weeks. Such solution is, however, extremely tenacious, and might prove of distinct value in certain applications. It is noteworthy in this connection that Hancock's early experiments with regard to the utilisation of vulcanized scrap rubber were directed to the formation of rubber cements.

A good deal of rubber solution is used in the golosh manufacture, for which purpose it is mixed with sulphur and litharge in order that it may subsequently become vulcanized. In America a large amount of rubber solution is bought as a cementing and waterproofing agent in the leather boot manufacture. Compared with what obtains in England, the American boot seems rather a weird production, what with brown paper, glucose, and rubber solution entering into its composition, though no doubt all-leather boots are to be had for the asking.

CHAPTER XII.

FINE CUT SHEET AND ARTICLES MADE THEREFROM.

The manufacture of cut sheet rubber is a special branch of the rubber industry, and is confined to two or three firms only. Besides the employment of considerable capital and expensive machinery, there are technical difficulties involved which necessitate expert knowledge on the part of either master or man. At one time the two large Manchester firms supplied the world's needs in this article, but at the present time besides the Leyland and Birmingham Rubber Company, which has taken up the branch, it is now made in France, Belgium, Germany, and Italy, and in a small way by two firms in America. Although for many years made only from the best Para rubber, second and third quality sheet is now on the market, the movement in this direction having been initiated by Germany some fifteen years ago. Seligmann in his book puts on record with what surprise Henriques found a quantity of oil substitute when analyzing a sample of German cut sheet. Where such sheet containing oil substitute is honestly sold for second or third quality there does not seem anything to be urged against it, except where it is used for certain classes of domestic and surgical goods. That many of such goods have shown a deterioration in quality in recent years is a fact of which there is abundant medical testimony, and it would be to the interests

of the community that doctors who imagine they are buying pure rubber should be informed of the fact when such is not the case. It is not suggested that any application of the Food and Drugs Act is desirable or possible in the case of rubber goods, but it certainly seems advisable for medical men to know exactly what they are buying, and to bring it home to them that cheap goods are almost of a certainty adulterated. Cut sheet rubber besides being used up in the factories of its origin is largely sold to smaller establishments, including private workshops, where it is made up into various small articles. This requires practically no machinery, the edges of the rubber being joined together by pressure, and the vulcanization as a rule being by the cold-cure system already referred to. A good deal of English cut sheet goes to Paris, where the *feuille Anglaise* has long been a well-known product, and is still considered the best obtainable. The Germans refer to it as Patent Gummi, though the reason for this synonym is not obvious. The great bulk of the cut sheet made has the brown colour which the rubber gains under treatment, and indeed in the thinnest sheets it is almost transparent. At the present day there is but little demand for green sheet, but red sheet, which is produced by adding vermilion to the rubber before being made into the block, is manufactured in considerable quantities. With regard to the process it will be readily recognised that it is necessary to get the rubber into a perfectly homogeneous condition, and further that it must be quite rigid if uniform sheets are to be cut from it. These effects are obtained by mastication, hydraulic pressure and freezing. The several processes briefly described are as follows :—The washed and dried rubber is warmed up or

broken down, as it is variously called, on large mixing rolls and is then put into a machine called the masticator, which consists essentially of an outer iron casing and a fluted steel roller revolving within it, the axis being set slightly obliquely. The rubber is squeezed between the roller and the casing, and the heat engendered serves to expel any traces of moisture and also air held in the pores of the rubber. To prevent the heat rising too high the casing has a jacket through which cold water circulates. After some time the rubber, which is now in the form of a sausage, is removed to make way for a fresh quantity. For rectangular blocks these batches of masticated rubber are put into iron presses about 6 feet by 1 foot, tightly screwed up and submitted to hydraulic pressure, after which they are frozen in an ice-house, an operation which takes a considerable time. These blocks can, of course, only produce sheets of their own dimensions. Where longer and wider sheets are required, three of the masticated batches of rubber are put into a vertical press and submitted to a pressure of one-and-a-half to two tons on the square inch. A circular block is then formed from which, after it has been frozen, sheets of as much as 600 yards in length can be cut. The cutting machine now employed for circular blocks is a triumph of mechanism, and it has been improved to such an extent that sheets of which 165 go to the inch can now be cut by one firm at least in the trade.

Generally described, the circular block cutting machine consists of a knife with a long straight blade, something like a mowing machine knife, and making up to 2,000 vibrations per minute. The speed of the knife can be varied by the cones which form part of the driving mechanism. The

sheets are cut in eighteen or twenty different thicknesses or counts. The rectangular blocks are put on a horizontal moving carriage, which can be raised or lowered to bring it up to the knife, and these machines, it may be said, are not of such a complicated nature or exclusive design as those used for circular block cutting.

Each firm has its own special machinery for compressing the blocks and cutting the sheets, and not unnaturally a good deal of reticence is displayed with regard to the details. In modern times the old system of freezing the blocks of rubber in a mixture of ice and salt has been succeeded by freezing chambers and refrigerating machinery, but even with this advance it may take quite two months to freeze a block solid to the core, which is necessary in order that a continuous sheet may be cut. As a refrigerating chamber may contain rubber up to £10,000 in value, representing locked-up capital, it will be recognised that this branch of the rubber business cannot be entered upon by firms without considerable capital resources.

Cut sheet can always be distinguished from what has been spread or rolled from a solution of the rubber in naphtha by the knife marks; at least, this should be the case. We live, however, in a progressive age, and Franz Clouth, in his book, refers to the use in some works or other in the Fatherland of an embossed calender, whereby rolled sheet has the apparent hall-mark of the knife-cut impressed upon it, and to such effect that any but the practised eye would be deceived. The author mentions this on the high authority quoted, not having any personal knowledge of the practice or any information as to whether it is limited to Germany or not.

Among the many uses to which cut sheet rubber is put, either in the vulcanized or unvulcanized condition, may be mentioned tobacco pouches, surgical goods of various kinds, what are known as "feeding-bottle" outfits, dress preservers, black india-rubber tubing, balloons, squeakers, and such like products of an advanced civilization. The electrical industry also makes considerable demands upon cut sheet in the form of strip in the cable manufacture, though in its special application of a first coating on the wire its popularity is also shared by spread and rolled strip.

To say a few words about some of the more important of these articles, commencement may be made with the tobacco pouch, which is largely, though by no means exclusively, made from cut sheet. The process is a comparatively simple one, the two pieces of rubber being cut or stamped out of the sheet to the required shape and the edges joined by pressure of the work-girl's finger and thumb. Vulcanization is effected by the hot vapours of chloride of sulphur, the pouches, put on to wooden moulds, being hung up in a steam-heated chamber.

Another process of vulcanization consists in immersing the pouch in a sulphur bath and afterwards heating it in steam. In the case of the well-known red crocodile pouch of Warne and Company, spread sheet containing red sulphide of antimony is used, and the vulcanization is effected by heat. This, of course, does not call for consideration under cut sheet goods, but it is mentioned here as a matter of convenience. Red steam-cured pouches are also made by the Davidson Rubber Company, U.S.A. On the Continent, the pouch manufacture has made but little progress, this being no doubt largely attributable to the fact that the

demand for the article is but slight. In Austria and the Balkans tobacco is almost universally carried in tins, and the author can testify to the difficulty in replacing a mislaid pouch. The methods of vulcanizing pouches just mentioned do not comprise all that have been or are at the present time in vogue, nor is the procedure in any particular factory necessarily limited to any one process. Three or four different methods may be in use in the same factory, according to the nature of the rubber and the form of the pouch. In certain cases where the use of heat is precluded the chloride of sulphur in the vapour cure is volatilized by the admixture with it of a small quantity of fuming nitric acid. This agent itself, or rather the red vapour of nitrogen dioxide which it evolves, has a sort of vulcanizing action upon the rubber. As, however, it may easily prove very destructive to the rubber if in excess, its use suggested, it is understood, first by Hancock, cannot be recommended. Where it is employed, as mentioned above, it must be considered merely as ancillary to the vaporization of the chloride of sulphur, and not as a vulcanizing agent in itself.

In making the small toy balloons the two pieces of sheet rubber are stamped out and joined together by a machine hammer, a very noisy operation, which causes the workgirls to stuff their ears with cotton wool. Where the rubber has to undergo distension it is important that the joints be well made, and this can only be done effectually by hammering. The vulcanization is brought about by dipping in a weak solution of chloride of sulphur in carbon bisulphide, an operation of some delicacy in the case of the very thin balloons. After the chemical fumes have thoroughly

evaporated by exposure to air in a tray of French chalk, each balloon is blown out by compressed air, a certain number generally bursting under the test, and having to go, therefore, into the waste rubber receptacle instead of into the packing box. It was more especially with regard to this and other branches of cut-sheet goods manufacture that the regulations as to the use of carbon bisulphide were introduced. Things are now carried on in a manner very different from what was at one time the case, and there is no reason to suppose that any permanent injury to health will accrue to those who are engaged continuously in this industry. At the same time, there is no doubt that the manufacturers and workpeople alike would be only too glad if the carbon bisulphide could be altogether banished in favour of a less inflammable and noxious substitute. Unfortunately, however, after the trial of numerous substitutes, manufacturers have been forced to go back again to their original procedure, no other liquid yet proposed having been found to possess the properties of carbon bisulphide in instantaneously softening the surface of the rubber so as to allow the chloride of sulphur to do its work. This in a general way, the author being aware that for certain purposes on a small scale the use of a hydrocarbon solvent in cold curing has been found satisfactory.

Rightly or wrongly, in the case of several classes of goods where the edges are joined together by pressure, this procedure has been held to constitute a source of weakness, and some manufacturers make a good deal of the fact that their goods are made by a seamless process. In such cases they have to be formed from a solution of rubber which is allowed to dry, in the case of hollow articles, on a mould of

the requisite shape. One advantage accruing to this form of procedure is that the rubber can be mixed with sulphur and subjected afterwards to the more satisfactory steam vulcanization.

Dress preservers were formerly made usually from cut sheet and vulcanized, either in the cold cure liquor or in the hot chamber with chloride of sulphur. Of late years, however, they have been made of greater stability by using rolled sheet steam vulcanized. Balata has also supplanted rubber a good deal in this branch. Certain American factories have produced these goods by various processes, one being the compound proofing of stockinette, and have enjoyed greater popularity for their products than have European makers, though to judge by the output of a large French factory this supremacy is being stoutly challenged. Now that tailors are using these hygienic adjuncts so largely, especially for uniforms, the business is likely to prove an increasing one, and the article is more suitably described by its French equivalent of *sous-bras*, than by the term commonly employed in England and America. The importance of neutrality in the finished product needs no emphasis, and effectual means to secure this must be employed where chloride of sulphur is the vulcanizing agent.

Cut sheet rubber, as used in the card-clothing manufacture, deserves a special paragraph, because it is made by a process different from that which has been described above. Card clothing, it may be advisable to explain, is used in the rotary carding machines of cotton and wool spinning mills. For its specific uses books on the textile manufactures should be consulted, but in general form it consists of layers of cotton cloth faced with india-rubber through which short steel wires

are placed close together. The manufacture is a somewhat special one, and is practically confined to certain works in Yorkshire and Lancashire wholly devoted to it. The object of the rubber facing to the cards is to give an elastic base to the steel wires, thus imparting to them the desired springiness. The rubber surface is sometimes of cut sheet and sometimes of spread sheet, the latter being used both pure and vulcanized. A good deal of card clothing is also made nowadays in which the rubber is altogether dispensed with in favour of a certain substitute. At the large works of Horsfall and Bickham, of Manchester, the whole of the rubber used, both cut and spread sheet, is manufactured. Here, as also at the Yorkshire works of the Card Clothing Manufacturers' Association, the rubber is not masticated, but after having been washed it is cut up into small pieces, dried in stoves at a high temperature, and compressed into a circular block by hydraulic pressure. The sheet subsequently cut from the block is of a lighter colour than the sheet which has been masticated, and it is always distinguishable from the latter by its peculiar mottled appearance. By this mode of manufacture it is claimed that a tougher and more durable sheet is produced than where the rubber has to undergo the mastication process, though the author is not aware of any reliable series of tests which may be accepted as indisputable proof of this assertion. In view, however, of the deterioration which it is generally agreed that rubber suffers in prolonged mastication, a *primâ-facie* case is certainly made out for the above contention. The use of sheet rubber in card clothing was first proposed by Hancock as far back as 1828, leather being the material commonly used at that period. It might be

mentioned that besides the three large Lancashire firms who make fine cut sheet for general purposes, small sheets of not more than a foot in length are made by one or two London firms in connection with the manufacture of surgical goods.

As vulcanization in the sulphur bath has only been mentioned in general terms, it may be of interest to give a more detailed account of the procedure followed for small cut-sheet articles. The made-up goods are put in a warm stove for some hours in order to perfect their joints, and they are then introduced into the sulphur bath upon forms of wood or metal, or in some cases a weight is tied to them to keep them down in the sulphur. They remain for about an hour with the sulphur at 240° F., when absorption takes place into the pores of the rubber. The temperature is then raised to about 270° F. for another hour or so, until the vulcanization is considered to be complete. Instead of going by the temperature and duration of time, it is usual for the man in charge to put a number of small pieces of rubber of the same thickness as the goods into the bath at the commencement of the operation. By a string which is attached to them these test samples can be drawn out from time to time and examined, and when vulcanization is shown to have been effected the goods are taken out of the bath and put into cold water. Their surface is covered with sulphur crystals, and these are either removed by rubbing with pieces of wood, or better by boiling in a caustic alkali solution, whereby the rubber becomes of a deep black shade. A subsequent polishing process may also be utilised to give a glossy appearance to the rubber.

CHAPTER XIII.

ELASTIC THREAD.

It has been already mentioned that the monopoly first enjoyed by Macintosh and Company, and afterwards shared by one or two other English firms, has of late years been challenged by other countries. Although it is safe to say that England is still by far the largest producer, yet the manufacture is to-day carried on in the United States, Germany, Italy and Russia. With regard to France, which is a large user of the material, the manufacture after having been carried on on the small scale for some years has now ceased, though it was in Paris that the greatest interest was at first taken in the subject, though the threads were made by quite a different process than that afterwards adopted on the large scale in England, and universally employed at the present time. In the original factory of Rattier and Guibal, at Paris, and into which Hancock introduced his process, the threads were either cut with a knife from rubber sheet, or were produced by forcing a thick paste of rubber in naphtha through apertures in an iron plate, and allowing the naphtha to evaporate upon a surface covered with French chalk. After the discovery of vulcanization, and the possession of the English patent therefor by the firm of Charles Macintosh and Company, the original French method rapidly became obsolete, and in the fifties the

resources of the Manchester factory were kept taxed night and day to supply the demand that arose. The manufacture, though involving no apparent difficulty, is yet one in which considerable knowledge of detail is necessitated if expensive mistakes are to be avoided ; moreover, workmen capable of undertaking the dozen or more different operations involved are by no means easily to be picked up. Owing to these circumstances, and also to the fact that the profits obtainable nowadays are hardly commensurate with the risks involved, this branch of the trade has seen less competition arise than is perhaps the case in any other branch. In speaking of France, it ought to be said that the manufacture of thread on modern lines was started a few years ago, but is not now carried on, though the country still remains prominent as a producer of elastic webbings, the extent and artistic merit of these productions being amply demonstrated by the exhibits at the last Paris Exhibition.

Elastic thread should, if properly made, stretch to seven times its length without breaking. This of course necessitates the use of the best quality rubber, and the onward march of time has witnessed in this branch none of that substitution of lower-grade material which has been so much in evidence in many branches of the manufacture as the result of competition. With elastic thread no tinkering with the established practice of the past is permissible ; it would at once spell ruin, a fact which is acknowledged even in Germany. Except in the case of the mineralized red thread, produced by William Warne and Company, Limited, of Tottenham, and which owes its colour and special properties to antimony sulphide, elastic thread is composed exclusively of pure Para rubber and sulphur. Briefly

summarised, the process of manufacture is as follows. The rubber is dissolved, or "let down," to use a factory expression, in coal-tar naphtha to which the requisite amount of flowers of sulphur has been added. The resulting "dough" is then mixed to a homogeneous mass on immersing rollers or in a pug mill. The next process is to spread the dissolved rubber out into a sheet, and this was at one time always done by means of a spreading machine similar to what is described under the heading of "Waterproof Cloth." Modern practice, however, enjoins the use of the calender, whereby a sheet of the required thickness, or "count," is more readily obtained, and at a less cost in naphtha. The cloth on which the rubber sheet is spread, or rolled, as the case may be, is surfaced with a material which enables the rubber to be readily stripped therefrom when the naphtha has been evaporated off by heat. In order to effect the vulcanization the rubber sheet is stripped from the cloth and put round a hollow iron drum, being inter-rolled with cotton cloth in order to prevent adherence of the rubber. This being done, the drum is lifted by a crane and put into the vulcan pan and vulcanized in hot water, at 270° F. to 280° F., for a length of time which has to be accurately gauged by the man in charge from his knowledge of the composition of the rubber. Under-vulcanization or over-vulcanization have both to be rigidly guarded against as largely affecting the value of the finished thread. The vulcanization completed, the rubber is unwound from the cloth, pasted over with a solution of shellac in wood naphtha, and tightly rolled upon a wooden drum. The shellac causes the rubber to adhere closely and become, as it were, a rigid block, in which state it is taken to the cutting lathes,

where by means of rapidly-moving knives it is cut into threads, which are of course the length of the original sheet, say sixty-five yards. Elastic thread, it may be mentioned, was first cut in lathes in 1849, by Charles Macintosh and Company. The next operation consists in boiling the roughly-skeined threads in a solution of caustic soda in order to remove the shellac and the excess of sulphur present. It is then well washed in water, dried in a warm room, and stored in a dark place, after its elasticity has been carefully observed by mechanical tests. There is nothing calling for special mention in the lathes, and it will be easily understood that it depends upon the gearing by which the knife is controlled, and upon the thickness of the rubber sheet, as to what count of thread is produced. The count, by which term the dimensions of the thread are expressed in the trade, represents the number which laid on one another make an inch: thus, thirty-six, which is a common count, means that each thread is one-thirty-sixth of an inch wide and deep, it being almost universally cut in the rectangular form. As regards the elastic webbing manufacture, Leicester may be considered its headquarters in England, Derby and Nottingham also being closely connected with the trade. To follow the elastic thread to these towns would be to go beyond the scope of this book, but reference may perhaps be permitted to a point which closely concerns the interest of the thread manufacturers. The author has heard of numerous complaints in late years to the effect that elastic webbing is of a poorer quality than it used to be. Enquiry into this seems to make it clear that it is not the quality of the rubber which is at fault, but rather its attenuation. In other words, whether owing to competition or not, it has

become customary to use finer counts than of old, and these wear out sooner than the thicker counts, as is only to be expected. Support is lent to this contention by the fact that the prices of many classes of elastic webbing have been reduced in late years. Quite a different way of accounting for the occurrence of inferior webbing might possibly be suggested by the old-established English firms. It is only guess-work on the author's part, but it is conceivable that they put it down to the introduction of foreign-made thread into the weaving factories of the Midlands, a development of recent years which is not looked upon altogether with complacency in Lancashire.

A new use for elastic thread arose a year or two ago in connection with the rubber-cored golf ball, and considerable quantities were sold for this purpose. In the latest practice, however, this thread has been substituted by elastic ribbon or tape similar to that used by electricians, except that it is vulcanized. It is made from spread or rolled sheet vulcanized and cut on lathes to about three-eighth inch width. Judging by the rapid progress of events in the golf-ball world of late years, this last item of intelligence may be obsolete before this volume is published, but even if this proves the fact, a reference to what is not generally known is justifiable on the score of interest.

All users of elastic thread are familiar with the hard, brittle nature of that which is worn out by oxidation. No doubt the constant changes of temperature, slight though they may be, which the rubber experiences, both in the ordinary process of stretching and in the contact with the human body, tend to shorten its life. As regards the weaving process, at one time there used to occur wholesale cases of premature

decomposition. These were attributable, doubtless, to the use of a paraffin wax of too low a melting point as a lubricant during weaving, and in some cases certainly to oxide of copper in the black dye of the textile threads. As these sources of trouble are now recognised and avoided, litigation between the rubber manufacturer and the elastic-webbing manufacturer only comes up for comment as a matter of history.

CHAPTER XIV.

THE MANUFACTURE OF MECHANICAL GOODS.

WHAT are known in the rubber trade as "mechanicals," comprise a large variety of goods, the most important of which, valves, buffers, washers, hose and belting, are used in connection with machinery. The term is a convenient one for rough classification, though it must not be read too literally, as in accordance with trade-procedure goods will here be included which in their particular applications do not come within the purview of the engineer. Much of the machinery employed is common up to a certain point for all classes of goods. In all cases the rubber is compounded, and in practically all it is vulcanized in one or another form of pan or press. Probably in no two factories are the details of procedure identical, the actual composition of the batch of rubber and chemicals, or the "mixing," as it is usually called, being regarded as a trade secret to be known only to those immediately concerned. In order that this secrecy may be preserved as far as possible, it is the general rule not to allow foremen or workmen to roam into departments other than those in which they are specially engaged, so that it may often happen that a man may be an expert in half the manufacture of a particular article, and be in ignorance of the remainder of the processes it has to undergo. As a general statement, it will not be far from

the truth to say that there are very few real secret processes in the trade to-day, though, as so much depends upon close attention to detail, it is of little avail for a new concern wishful of emulating a long-established one to obtain a general description of a process. Unless the fullest details are available, the proposed competition may only result in loss to the instigator thereof, unless, haply, fortune favours his guess-work. There is no intention here to illustrate this precept by example from the pages of history, as manufacturers generally will acknowledge its truth. The rubber trade is not yet founded on such a scientific and sure basis that the services of the practical man who uses his experience can be dispensed with. Whether it ever will be is matter for conjecture. Suffice it to say that there is no immediate prospect of the practical man who knows how to get certain results being supplanted by those who have not gone through the mill routine, whatever the scope of their scientific studies may have been. But there are those who aver that chemistry ought to take a much more important place in the manufacture than it does. It is no use, however, shirking the fact that the limitations of rubber analysis are a bar to the service which the chemist can render the manufacturer. Chemistry has, of course, rendered many and signal services to the trade, especially during the last decade, but it has also failed in many directions where great things were expected of it. But not to go at too great length into generalities, what it is wished to emphasise is that in many cases it lies beyond the power of the chemist to unravel the secret processes of the trade, and that therefore the practical man who has worked these

processes, though probably without knowing the why and the wherefore, must still be considered the most important in the trade. It will be recognised at once that as long as everything goes smoothly, rule-of-thumb working does not call for condemnation ; when, however, as not infrequently happens, some bad work is turned out, the operator is likely to be quite at sea as to the cause, and as likely as not puts the blame upon some innocent substance or operation. The interests of the industry seem to demand that the rule-of-thumb operator of the past and the present should in the future be succeeded by one who combines a wide experience of the details of the manufacture with a thorough theoretical knowledge of the principles involved. A recent author rates the india-rubber manufacturers of this country for having as a class done little or nothing to develop the scientific side of their industry.

To proceed with matters of fact rather than controversy, the rubber and various chemicals, including sulphur, for any particular "mixing" having been carefully weighed out, they have to be mixed together into a uniform mass. This is done on the mixing rolls, which do not differ appreciably in general appearance from the washing rolls. Fig. 11 shows a pair of these rolls, and their character will be understood by a few explanatory words. There are two chilled iron rolls, about 3 feet by 16 inches in diameter. The surfaces are smooth, and they are geared to move in opposite directions at different speeds. They are hollow, so as to allow of steam or cold water being circulated to keep the rolls at the temperatures required for certain classes of rubber or compounds.

Except in point of size and capacity, these mixing rolls have

undergone hardly any alteration since their inception about seventy years ago, and they are in general use to-day. Mention should, however, be made of the double-acting three-cylinder mixing mill patented a few years ago by J. T. Wicks, the use of which it is claimed reduces working expenses, as the three-roll mill does twice the work of the

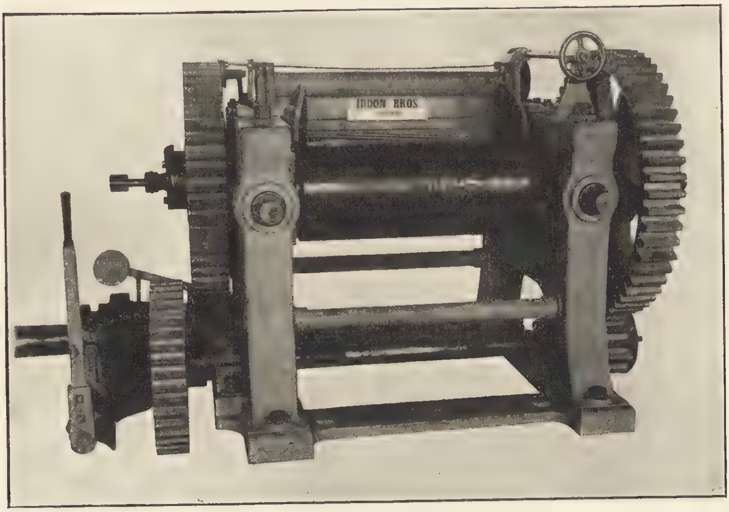

FIG. 11.—MIXING ROLLS.

two-roll, with the same cost for labour. Of course it is more expensive, but the compensating advantages make this a matter of no real importance in a large factory. Those in use at the present time have rolls 48 inches long by 14 inches diameter.

In mixing a batch of compound, the workman places the rubber on the rollers, which are adjusted apart, and it is after a time formed into a sheet which adheres to the

slower-moving front roller; the various powders are then gradually sprinkled on to the rubber and get incorporated with it. From time to time the workman slits the rubber sheet through with a knife, putting the several pieces between the rolls to again be formed into a sheet. After this process has been repeated a number of times, a perfectly homogeneous mass is obtained. In general terms, a batch weighing about one cwt. will take thirty to forty minutes, it being important that perfect homogeneity be obtained in as short a time as possible, as over-working tends to injure the rubber.

The operation known as "breaking down" or "warming up" has for its object the restoration of plasticity to washed rubber which has got rigid by being kept in stock. This operation does not call for special mention, being usually carried out on rolls similar in design to the mixing rolls. We may now follow the batch of mixed rubber to the calender, where it is rolled out into sheets of greater or less thickness, according to the goods to be made. The calender (Fig. 13) consists essentially of a system of chilled iron rollers, two, three or four in number. Three or four is the usual number, though some have been built with as many as six rollers. Such multiplicity does not, however, appear to have answered expectations, and the four-roll calender may be taken as giving the maximum efficiency in the purposes of its application. The rolls, like those of the mixing mills, are hollow, to allow of the circulation of steam or cold water as required; their surface is perfectly smooth, the main requisite of a high-class calender roll, or bowl, as it is more commonly termed, being a uniformly plane surface. The *modus operandi* is briefly

as follows, and it will be readily understood by means of Fig. 12 showing a three-bowl calender.

The workman having passed the compounded rubber two or three times between rollers, places it in small pieces at a time between the two top bowls marked 1 and 2. It at once forms a thin sheet which adheres to the bowl 2, and then passing between bowls 2 and 3 it is rolled on to a sheet of calico which is being continuously

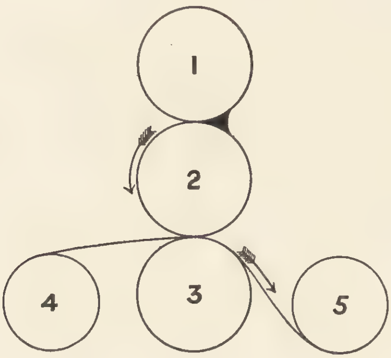

FIG. 12.

unrolled from the wooden roller or box marked 4. The rubber and calico are then rolled up on the box marked 5. The rolling up with calico is necessary in order to prevent the layers from adhering to one another and becoming a solid mass. If a solid cylinder of rubber is required, as is occasionally the case, the rubber sheet passes from the calender without being inter-rolled with calico.

Hose.—India-rubber hose is made of many different descriptions and qualities according to the purposes for which it is required. The enumeration of all the varieties

and a reference to their uses would occupy too much space, so a selection will be made of those in most general demand.

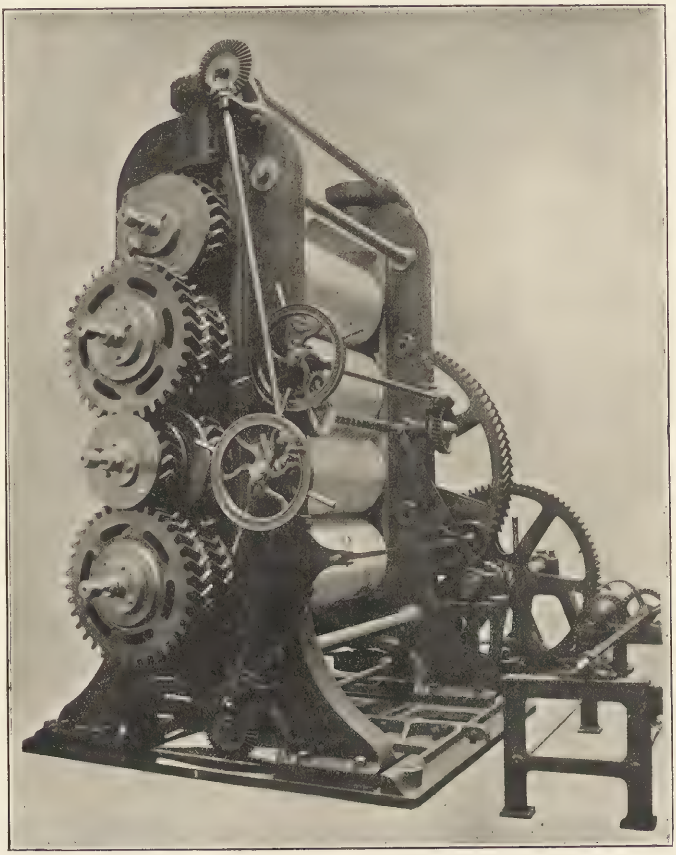

FIG. 13.—FOUR-BOWL CALENDER.

Although hose is supplied by the manufacturers for specific purposes, it is often put by the purchaser to uses for which it is not intended or adapted. Thus the ordinary delivery

hose is not intended to stand heat or acids, and if subjected to them will accordingly prove defective. In steam-raising the tendency of the age is to employ higher and higher pressures, and the conditions under which rubber hose valves, packings, etc., are used nowadays are, as a rule, much more trying than was the case twenty years ago. Where the rubber manufacturer is made fully acquainted with the conditions of use he can so compound his rubber as to give the best results possible. Of course, when no details are furnished him, it is not surprising that unsuitable rubber is sometimes supplied. Rubber hose is familiar enough on the lawn and in the garden, and in Continental cities for street watering. Large quantities are used by the railway companies for vacuum and Westinghouse brakes, in which connection its use is likely to be largely extended in the near future, if the fitting of fast freight trains with power brakes is made compulsory. For the steam heating of passenger trains rubber hose is also largely in request. Contractors use it in special forms, sometimes up to 3 feet in diameter, for suction purposes; while some fire brigades, notably the Metropolitan, use rubber-lined flax hose instead of ordinary textile hose. Brewers, again, use rubber hose, specially prepared so that it shall not communicate any taste or impurity to the beer. For a good many purposes rubber hose has to be armoured, that is lapped externally or internally with iron wire. In some cases this armouring is embedded between the layers of rubber. The ordinary hose for the vacuum-brake couplings is internally wired, so as to prevent collapse by atmospheric pressure. External wiring, in addition to a covering of marlin or hemp cord, serves to protect hose used in rough work from damage.

Only in small-bore tubing for special purposes is rubber used alone, in most cases canvas forming a prominent part; indeed, in one or two cases the rubber is merely used in a thin layer to make it water and air proof, flexibility being of no moment.

In making up the hose hand-labour is mostly employed, though a special lapping machine can be used, the calendered rubber sheet, which is usually strongly compounded, being cut in strips and rolled spirally round an iron mandril. On this a layer of canvas is rolled. In the best work the canvas is not used plain, but has had what is known as a friction coat of rubber put on it by the calender bowls, which for this purpose are set to revolve at different speeds. The rubber is thus forced into the interstices of the canvas, and its presence at the same time guarantees a perfect contact between the textile material and the layers of rubber. The making up of the hose having been finished, it is dusted with French chalk, lapped in cloth, and is then ready for vulcanization. A number of lengths of hose, which may be 40 to 60 feet long, are placed on a tray filled with French chalk; the tray is put on a trolley and run into the vulcanizing pan, in shape like an elongated boiler, of 4 feet diameter. The lid having been closed and secured by bolts, steam at about 40 lbs. pressure is turned into the jacket by which the pan is surrounded or into the interior of the pan. The time of vulcanisation depends on the quality of the rubber, the amount of sulphur present and the temperature, and may be anything from 40 minutes to 2 hours.

In the case of imbedded wire hose, the extra operation of coiling the wire on to the soft rubber before the hose is

completely made up is done by a machine. Where all-rubber tubing of comparatively narrow diameter is being made, the process is simpler, pieces of the mixed compound rubber being fed into a machine of the type of a lead-pipe drawing machine, with a mandril in the nozzle; for a figure of this, see under "Cab Tyre Manufacture." The tubing as it emerges drops on a circular tray containing French chalk, which slowly revolves, allowing the tubing to be deposited concentrically. The tray is then covered with a lid or sometimes left open, and is placed in a circular vulcanizing pan to be cured in open steam. In the manufacture of rubber-lined fire hose two or three different methods are adopted, the most modern being to force the rubber compound into the interior of the flax hose. Experience has shown that the amount of working necessary to get the best rubber sufficiently plastic for this operation has the effect of shortening its life,[1] and a cheaper and more resinous rubber is found to give equally good results in the end, this not requiring to be masticated to the same extent before being used. Rubber-lined fire hose, besides being heavier than the unlined, is, of course, more expensive, and it may be asked wherein do its advantages lie. The answer to this is that by diminishing friction it enables the water to be ejected at a higher velocity. From some figures obtained by J. R. Freeman, an American authority, who experimented on behalf of some insurance companies, it appears that whereas ordinary canvas hose loses 27 lbs. pressure per 100 feet length, a smooth rubber-lined hose loses only 10 lbs., this particular test having reference to the discharge of 250 gallons of water through a $2\frac{1}{2}$ inch hose. These

[1] This is a point on which difference of opinion obtains.

figures are of interest, but it is important in tests of this sort to note the quality of canvas hose used. In this test the best quality may or may not have been used; nothing is said on this point. In the best quality fire hose, in which a fine yarn is woven in a special way, there is likely to be less friction than in common qualities. Naturally the rubber-lined hose will not stand the same bursting pressure as the unlined, but it will stand all that is likely to be required of it.

Though principally used for small-diameter seamless hose, the tubing machine referred to above is also utilised for rubber tubing of larger diameter, which has been made from sheet rubber doubled into cylindrical form. By passage through the die of the machine the edges are firmly united.

With regard to railway hose, that which calls for most notice is what is used for steam heating of passenger coaches. The rubber for this purpose should be a special quality to resist the continuous heat. Though a good deal has been heard of the defection of this hose, the blame in many cases is attributable to the way in which it is used. Enquiry has revealed the fact that there is considerable difference of procedure on our railways; in some cases steam at 80 lbs. to 100 lbs. pressure goes into the pipes, and in other cases it is always passed through a reducing valve so as not to exceed 40 lbs. Again, it is an open question whether more damage is not done in the continual coupling and uncoupling than by the steam; certainly this is the case on the hose of the tender. The partial use of flexible metallic hose not having been considered satisfactory, there is evidently no choice but rubber, and this should be treated as fairly as possible. That a great variation in the steam pressures admitted

exists, has been noticed by the author in a series of observations on steam heating on home and foreign railways, and where guarantees are given with hose enquiry should be made as to the conditions it is likely to experience.

Buffers, Washers, Rings, etc.—In making up these and

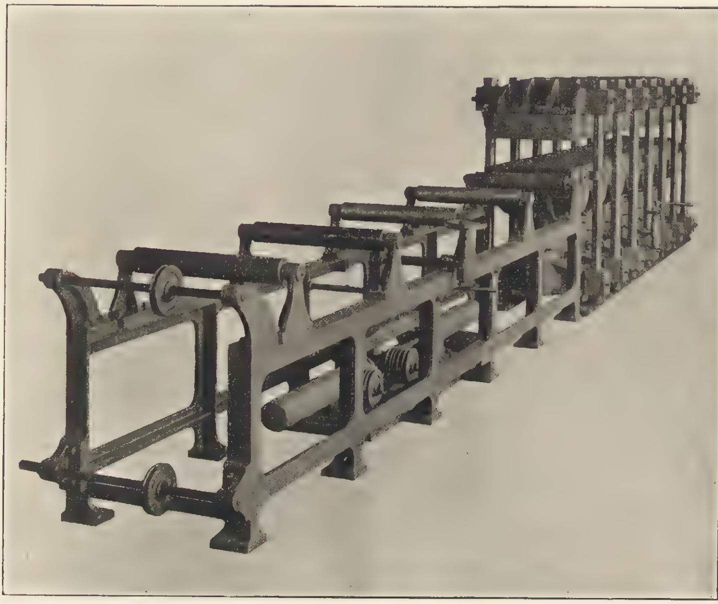

FIG. 14.—BELTING VULCAN PRESS.

numerous other articles the sheet from the calender is unwrapped by machinery, the cloth going to one roller to be used over again, and the rubber being rolled up over a mandril to form a cylinder of the necessary dimensions. If washers or rings are required the tube is wrapped in cloth and taken to the vulcanizer. After being vulcanized the outer cloth is removed, a mandril is inserted, and the tube

made to revolve in a lathe before a knife by which means the rings are cut off.

In the case of buffers, these are cut off the unvulcanized rubber, put into tightly-fitting iron moulds, and then vulcanized. Valves are cut out of calendered sheet, which has been doubled or otherwise built up to the required thickness, and then vulcanized. The valves are then cut out by means of a vertical saw moving at high speed. Large buyers like the Admiralty do this work themselves, buying the vulcanized rubber in rolls from the manufacturers.

Rubber belting is made by spreading or calendering compounded rubber on canvas sheet both sides, cutting this into strips of the required width and building these up to the necessary thickness. Vulcanization is effected in presses the lower plate of which is made so as just to fit the belt and to keep it under pressure during the process. Fig. 14 shows one of these belting presses. Many other goods besides are vulcanized in presses, which in large works are often worked by hydraulic power. Fig. 15 shows one of these presses, which can be fitted with a screw stretching arrangement, or for hydraulic power as required. In the latter case an accumulator and steam pumps are required, these not being shown in the figure. Sheet destined for valve making may be vulcanized in these presses, or it may be wrapped round a drum covered tightly with calico and vulcanized in hot water in a manner similar to thread sheets. Some manufacturers use one method, and some the other, according to the light of their individual judgment. In the press vulcanizers the plates are hollow for the admission of steam, and they are usually lagged to prevent radiation. It will be noticed that the rubber does not come into contact

with the steam, but only with the steam-heated metal of the press. Articles which are tightly fixed in separate moulds are sometimes vulcanized in open steam; at other times in

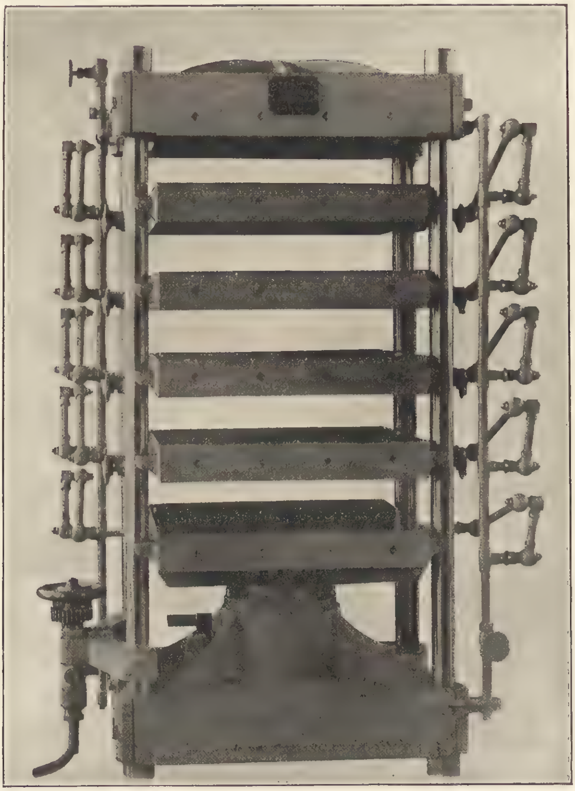

FIG. 15.—SIX PLATEN HYDRAULIC VULCAN PRESS.

presses. These moulds, which form a considerable part of the rubber manufacturer's stock-in-trade, represent a large capital outlay, and it is because of the expense involved that manufacturers often show themselves averse to executing

small orders which require moulds not kept in stock. As a rule the moulds are of iron only, but for special purposes they have a white metal lining. The exact temperature of vulcanizing is a matter that requires close attention. On the Continent the ordinary steam-pressure gauge is in common use, while in England it is the general rule to use the Fahrenheit thermometer ; this is put into a receptacle in the lid of the vulcan pan or into the steam chamber of the press, the receptacle as a rule having a small quantity of mercury in it. Thermometers for the several purposes of a rubber factory are specially made, and though there is no need to go to the expense of a Kew certificate, it is desirable to have them tested occasionally against a standard instrument. Electrical recording arrangements and the recording drum aneroid have had trials, but owing to their expense and liability to get out of order, together with the indifference, if not active hostility, shown by under-managers and foremen towards new-fangled appliances, they have usually had but a short spell of life where they have been installed—that is as far as the author's own experience goes. In America it is understood that recording instruments have a wide application. Among one or two other goods which space permits of mention we have rubber-covered rollers for paper-making machines. In fixing these to the iron roller it is customary to have a vulcanite layer next to the iron, the soft roller being then vulcanized on to the hard rubber. This class of work is somewhat difficult to execute satisfactorily, as special means of attaching the vulcanite to the iron have to be adopted. Certain British firms make a speciality of these rollers, but the entry of Sweden into rubber manufacturing has already led to Swedish rollers

being used instead of British in Scandinavia, at any rate in the paper-works in the North of Norway visited by the author.

A new article, the manufacture of which in the last two or three years has assumed imposing dimensions, is the rubber heel-pad. They are now made by the million, and call for a greater or less amount of rubber according to the quality. The manufacture is a simple one, consisting of stamping out the heels from compounded rubber, which need not have been calendered, and vulcanizing in steam in moulds holding a dozen or more heels each. They are also vulcanized in hydraulic presses. There are many so-called patent heels, sold by firms who get them made under contract at the rubber works, the particular shape and marking being given to the heels by the moulds during vulcanization. Though these heels can be bought of best quality, combining elasticity and resistance to abrasion, so many of a low quality have been made of late that the reputation of the goods generally is bound to suffer eventually, if, indeed, this is not already the case. Rapidity of ouput is a feature of this branch, and the rubber mixing is arranged so as to occupy only about a quarter of an hour or twenty minutes in vulcanizing. To give some idea of the magnitude this business has attained, it may be mentioned that the Wood-Milne Company, who first put the heels on the market in 1896, now have a yearly output of over twenty million pairs.

India-rubber packings for piston rods, gauge-glass rings, etc., etc., do not at the present time enjoy the popularity they once did. Two main reasons may be adduced for this—firstly, the low quality of the rubber, which resulted

from competition and a desire for cheapness on the buyers' part; and secondly, from the increasing use of higher steam pressures, for which rubber was found less suitable than other materials. Asbestos has now largely replaced rubber, being used either alone or wrapped round an india-rubber core. There is the competition, also, of various other materials, such as vulcanized fibre and numerous other proprietary articles, each of them claiming to be superior to the others for use with high temperatures. In such packings the bulk of the material is naturally heat-resisting, only a small proportion of rubber, or in some cases balata, being used to give flexibility and to act as a cementing material for the mineral matter. America may be credited with the lead in modern high-pressure steam packings, though of late European firms have taken a leaf out of America's book, and gone a long way towards supplying their own requirements. The metallic packing, first introduced from America, is now made in Great Britain, but although it has decided advantages over rubber, asbestos, etc., especially in locomotive and marine work, its high price has caused it to lag behind in popular favour. The name of "Tuck" is so well known in connection with packings that it is now used as a generic term by Continental manufacturers, and it must no longer be assumed that all packing called "Tuck" has emanated from the Lambeth works. From what has already been said about vulcanization, it will be at once understood that vulcanized rubber packing, in contact with heated surfaces, will become over-vulcanized and hard. In order to obviate this as far as possible it has been sent out decidedly on the soft side, vulcanization being completed when the packing is in use.

As in the case of rubber hose, it is always desirable for the manufacturer to have some detailed information as to what the packing is wanted for, and he will then be in a position to supply what will give the best results. To comment on the various uses of engine packing would occupy too much space, besides being somewhat beyond the scope of this volume, which is primarily concerned with the nature and manipulation of rubber.

With regard to the manufacture of india-rubber packing, there is no special machinery required, and the making up does not call for more than a word or two of explanation. As in hose manufacture, the textile material has a rubber coating put on it by the friction calender, and this is made up on a rubber core to either round or square section. In the case of very cheap packing the textile used, often old hempen sail-cloth, will not stand frictioning, and has to be coated on the spreading machine. The packing, after being made up in lengths, is vulcanized either in the press or pan. With regard to the textile material used, there is really no object in using first-class quality, because cotton begins to tender at 280° F., a fact which, in modern times, has led to the substitution of woven asbestos, which can be coated with rubber on the spreading machine. For certain purposes metallic gauze is also introduced into the asbestos. In an Admiralty specification for a special packing of this composite nature, an alloy of lead and tin is used, in which the tin present must not be below 10 per cent.

In addition to the belting used for machine driving, rubber belts of large size are employed as conveying or picking belts in grain elevators, there being one of these in the United States three miles in length. As picking

belts they are used in metal mining, and in the ore-concentrating machine known as the Frue vanner, a rubber belt four or five feet wide forms the buddling surface. For the purpose, however, of ore concentration the rubber-belt machine finds a severe competitor in the Wilfley table, in which the rubber surface is replaced by linoleum, and there is the less inducement for English manufacturers to compete in a business so largely monopolised by the American rubber firms. All the same, as the revival of tin mining in Cornwall on modern lines is proceeding apace, the Frue vanner may be expected to reign in the place of the round buddle of old memory, and home manufacturers should see that their own inaction is not the cause of the necessary rubber fittings being imported. A new form of belting is that recently patented by Reddaway and Company especially for machine driving in damp climates. This is the ordinary woven cotton and hair belting, with a layer of vulcanized rubber on each side, the absorption of moisture being thus effectively prevented.

Rubber Pavement.—The rubber pavement recently put down at the Savoy Hotel, London, at a cost of £2,000, has drawn renewed attention to a use for rubber which was initiated thirty years ago. In 1875 rubber pavement was put down by Charles Macintosh and Company, at the Midland Grand Hotel, and also at Euston Station in 1881. Although worn parts of the latter have recently been relaid, the suitability of the material for resisting wear and tear, and at the same time acting as a noise-deadener, must be considered amply proved. Certainly a critic correctly points out that so far such pavements have only been used under a roof, and that the bulk of the vehicles passing over it have been rubber

tyred. These points rightly call for consideration by those who are contemplating putting down rubber pavement under more severe conditions, but they are by no means conclusive evidence against the prospective longevity of such pavement for street use. It may naturally be expected that the wear and tear will bear some definite ratio to the amount and severity of the traffic, points on which reliable data are yet wanting. Of course, with rubber at its present price, the general use of rubber pavement is out of the question, though investors in rubber plantations, fearful of over-production ten years hence, profess to see in the rubber pavement a guarantee of sustained dividends. Somewhat allied to the pavement is the rubber flooring, which, in the interlocking pattern, has recently attracted some attention. In connection with this development the New York Packing and Belting Company have been to the fore in America, and we shall probably see it replacing linoleum in England to some extent before long.

Rubber stair treads and mats have long been known. Of late the demand for the latter has shown an increase, and the quality of the rubber has been improved. Twenty years ago it was a commonplace tale that the Saturday sweepings in the rubber factory went into perambulator tyres and door mats in the following week. There was exaggeration no doubt in this, but still the quality of the rubber formerly used was undeniably low. In making these mats the holes are machine or hand punched out of calendered sheets built up to the required thickness, vulcanization being effected in the hydraulic press. Other mats are moulded, taking their form from the vulcan press plate.

Rubber Soles for lawn-tennis shoes are commonly classed among mechanical goods, their manufacture being carried on in ordinary rubber factories, and not specially by those who make goloshes. The rubber sole is of very varying composition and quality according to price. The manufacture is carried out on similar lines to that of heel pads, an excess of sulphur being generally used in order to ensure rapid vulcanization ; in fact, it is not uncommon for three charges to be turned out in one hour from the same vulcan press. The wearing surface is either plain or corrugated according to the mould used in the vulcanization. These soles may be stitched on to the leather sole in addition to being cemented with rubber solution, though the stitching is frequently omitted as being superfluous. Although no facilities are offered by the retail trade for replacing worn soles by new ones, the uppers of a good tennis shoe will always stand two if not three soles, and those who have an eye to economy would probably find no great difficulty in getting new soles put on at the rubber factory at a cost considerably less than that of a new pair of shoes. Of course, a pair of soles might be purchased and put on the shoes at home with rubber solution, but unless the operator possesses some degree of technical knowledge this procedure is not to be recommended.

CHAPTER XV.

SUNDRY RUBBER ARTICLES.

UNDER this non-committal title it will be convenient to refer to some rubber goods of more or less general interest which do not call for a chapter to themselves.

Hollow Balls.—Lawn-tennis balls and playing balls, both plain and coloured, form a branch of the trade limited to only a few firms, who do the business on a large scale. It is essentially a season business, particularly in the case of lawn-tennis balls, the ball department being worked at full pressure from January to June, while during the rest of the year things are very quiet. In making a lawn-tennis ball the compound sheet rubber is cut into oval pieces accurately with a knife and metal shape, a bevelled edge being given to facilitate subsequent adhesion. Two or four of these pieces, according to their form, are joined together by pressure on the edges, and before quite closing up, a small piece of pure rubber is stuck to the inside, its position being shown by a mark on the outside. A little ammonium carbonate is then put inside the ball, and the aperture made up. The ball is then put into an iron mould and vulcanized in steam. After this process, in which it is kept inflated by the dissociation of the solid ammonium carbonate into gas, it is permanently blown up by compressed air, the sharp nozzle of the blower being inserted at the point where

the piece of pure rubber is enclosed in the ball, the object of this being to ensure the closing up of the hole made by the nozzle of the blower directly the latter is withdrawn.

Another process of making balls replaces hand by machine labour. This process, which employs the machine patented by Cox, was in regular use for some years by the Eccles Rubber Company. It is certainly economical in labour, but requires a better class of rubber compound than that which is usually associated with the ball trade, and when the better rubber is used the saving on labour is neutralized. Perhaps this statement ought to be qualified by the remark that taken all round the quality of the hand-made ball does not usually fall below that with the working of which the Cox machine can show economies. Cox's machine was not the first attempt to minimise hand labour in ball making, as it was not patented until some years after Hille's patent machine had been in operation at the Eccles Works. In the latter machine two segments of rubber were formed into a ball in the mould, while in Cox's the ball was formed from a single piece, but its advantage over the earlier patented machine lies in its capacity for producing a properly inflated ball.

Hollow playing balls are usually made from four segments, in a manner similar to that described above.

Hollow balls may be classified in three divisions, ordinary grey balls of varying diameter, the same coloured by hand-painting, transfer pictures, etc., and lawn-tennis balls. The hand-painting does not call for such artistic merit as we find in the pottery trade, but an apprenticeship of some duration is required to do the work neatly and expeditiously. The most important class is the lawn-tennis ball, this

having to satisfy specific requirements of weight, size and "bounce." After vulcanization they are covered with two segments of felt, which dovetail one into the other ; a little rubber solution ensures the adherence of the felt to the ball, though in addition it is necessary to sew the seams. Large numbers of these balls are sold in the uncovered condition to other firms, who do the covering and put them on the market. It is somewhat of an anomaly that the demand for hollow balls is nearly always in excess of the supply, and it might be thought that the few firms in the business would have met with competition. The fact that the trade is so largely a season one, however, no doubt deters many who wish their capital to be employed all the year round. Besides, there is the ever-present bugbear of German competition, balls being sold in Germany at a price which allows of any surplus being sold here at what must be an actual loss. It may be mentioned that the British and German producers now meet once a year to decide on prices, though there is nothing in the nature of a cartel or trust.

The Rubber Sponge.—This article, which has attained prominence and a considerable degree of popularity in Great Britain within the last few years, was until quite recently a monopoly of the Russian-American Rubber Company, of St. Petersburg, and a large number, if indeed not the bulk, of those seen in the shop windows in England bear a label inscribed in Russian characters. The mystery attending the manufacture has been dispelled by some German and American firms, who are now in competition with the Muscovite kingdom, but the author is not aware of any British firm having yet succeeded in following the

Russian lead. In the rubber manufacture generally, as will have been gathered from preceding chapters, porosity is an enemy to be specially guarded against, the presence of moisture in the ingredients of a "mixing" having a potent and generally sinister effect. In the case of sponge rubber porosity is just what is wanted, but there seems to be a decided difficulty in getting enough of it when you want it as a would-be manufacturer once remarked. There is no demand as yet for a sponge that will take the place of pumice stone, a material to which some of the experimental work done may be fitly compared as far as hardness is concerned. By the way, it is interesting to note that one author states the rubber sponge is of British origin.

Surgical Goods.—With regard to this branch references have been made elsewhere to topics of general interest, and there are no special processes of manufacturing which demand attention. In some instances there is as much delicacy required in production, as there is in talking about them, and a few generalities will perhaps suffice for the purpose of this volume. Hollow articles of compounded rubber are fashioned by hand, and, a pinch of ammonium carbonate having been added, are vulcanized in iron moulds in the same manner as hollow balls, a longer time being required owing to the thickness of the rubber. Where the compound rubber is required to be black, lamp black is used, lead compounds being barred as likely to lead to trouble. For red rubber the pentasulphide of antimony is used, oxide of zinc being the principal "filler" in white rubber. Gloves finger tips and many other articles are made up of pure sheet, and are vulcanized in two or three

different ways. A special feature appertaining to surgical goods is the enamel, for which the several firms have their own formulæ. This has to be made so that it will not crack off, a result which has been attained with varying degrees of success by firms engaged in this branch. Rubber forms a component part of this enamel, and vulcanization is usually effected by dipping in the cold cure solution.

Stationers' Goods.—Erasing rubber calls for mention, if only as the first rubber article sold to the public. The original form in which this came into commerce was a piece cut from the raw Para rubber, and although such is still to be met with in drawing offices, that which is usually sold at the present time is vulcanized rubber, mostly in the heavily compounded form. A prominent firm in this connection is the Bavarian house of Faber & Co., having also large factories in America. The rubber department is, of course, only an accessory to the rest of the business with which the name of Faber is associated, but in itself it is large enough to warrant this special reference.

Rubber bands like thread require the quality of elasticity in its supremacy, and the mineral matter the well known red bands contain is limited to the pentasulphide of antimony, to which they owe their colour. In the manufacture the rubber mixed with antimony sulphide and sulphur is put through the tubing machine, and the resulting tube having been vulcanized on a mandril in open steam, is cut into bands by lathes. The excess of sulphur is then removed by boiling in a solution of caustic alkali. The vulcanization must be timed very exactly if the bands are to preserve their elasticity; if overdone they will go hard in a short time and break under tension. The boiling in

alkali, usually caustic soda, lasts for three or four hours, and it is important that the liquor should be clean and not contain too much sulphide of sodium, resulting from previous use, a remark of general application in the desulphurization of vulcanized rubber goods.

Dental and Stamp Rubber.—Rubber compounds for these purposes are prepared in the factories and sold in the unvulcanized state to be vulcanized when they have received the shape in which they are destined to remain permanently. Although there are one or two firms in Great Britain making a speciality of dental rubbers, these are more extensively made in the United States from formulæ which are not very generally known. The manufacture has more reference to vulcanite than soft rubber, and it is important for the dentist to be able to depend with confidence upon the composition of the rubber for which he pays such a high price. Oxide of zinc, sulphide of zinc, and vermilion are chemicals largely used in these rubbers, into which it is important that nothing of a decidedly poisonous nature should enter. The methods of moulding in plaster of Paris and vulcanization in steam, although performed in special apparatus, do not differ in principle from what has already been mentioned, and those who are especially interested may be referred to books on dental surgery. Dental dam, or rubber sheet, is usually pure spread sheet vulcanized, though the vulcanized cut sheet is also used to some extent. It is advisable that first quality sheet only should be used for this purpose, the normal terrors of the dentist's chair being quite sufficient without the added objection of sucking oil substitutes. The vulcanization of dental dam is sometimes effected by

chloride of sulphur vapours, and in the case of spread sheet which has been mixed with sulphur, steam vulcanization is employed. The surface is sometimes sprinkled with aluminium powder, the idea being to give a reflecting surface to aid the operator. By way of stiffening the compound dental rubber, a recent patent of the Dental Manufacturing Co., of London, has reference to the insertion of fine nickel wire gauze within the rubber. Although it may be new to use nickel for this purpose, it is interesting to note that over twenty years ago platinum gauze was used. At the present price of platinum, £8 per ounce, double that of gold, it is not surprising that it has been sought to use a less costly metal for a purpose where the special properties which make platinum so valuable do not come into consideration.

Bottle Rings.—Rubber rings, commonly called Codd's rings, are largely used for beer and aerated water bottles, a special ring being also made for fruit jars. For these purposes a demand is made on the rubber which is practically unknown with regard to the bulk of goods manufactured. It is required that the rubber rings be as far as possible odourless, and in order to fall in with this suggestion certain brands of rubber have to be rigidly tabooed. If price were no object the desired end could be satisfactorily attained by the use of the best Para rubber, but unfortunately the conditions of business rarely permit of this, and so various expedients have been resorted to in order to remove the smell of inferior rubbers. Very little success has, however, been attained in this direction, and for reasons which seem pretty obvious. Although pure rubber has an odour *sui generis*, this is by no means powerful or

disagreeable, and what trouble there is about the smell may be put down principally to the albuminous matters which in small quantities remain in the washed rubber. Various oxidizing agents will destroy the smell for a time, but owing to the fact that the action is only superficial, the remedy proves to be but temporary, and the trouble soon arises again. It must not be taken that the use of oxidizing agents is advocated as desirable; indeed, grave suspicion attaches to any such procedure, because there is every probability that what will destroy the albuminous matter will have an injurious action upon the rubber also. What is known as Bourn's process for deodorizing rubber goods is based on safer lines. This consists in placing the goods in trays of charcoal in a warm stove. Although, however, this is referred to by previous writers as a process of value, the author has never found it to come up to expectations, that is, with regard to permanency of result. As in the case of oxidizing solutions, the undoubted deodorization which is at first effected soon gives place to the old state of affairs.

To turn to another point connected more particularly with fruit and salmon jar rings, it is important that the rubber be prepared especially to withstand, in the first case, vegetable acids, and in the second case, oily substances. This is a matter which has closely engaged the attention of the manufacturers with satisfactory results, and it need hardly be said that in view of the possible action of the contents of the jars upon the rubber, the use of certain metallic oxides, harmless enough for other goods, has been recognised as undesirable. Although in some quarters the use of rings made of asbestos, felt, or other material has been advocated in the interests of hygiene, it

does not seem to have been proved that the slightest danger need be apprehended from rubber rings where these are of a quality suited for the purpose. While on this question of hygiene a word or two may be said with reference to the charge brought against beer bottle rings a year or two ago, to the effect that they had a good deal to do with the spread of a certain fashionable disease. It was contended that the red sulphide of antimony, which such rings usually contain, either went into solution or separated out as a powder at the bottom of the bottle, and that in either case it led to the specific trouble. The statement that the antimony goes into solution may be dismissed as baseless, though, with regard to the sediment at the bottom of the bottle, it may be taken that it consists of particles of rubber, and not of separated mineral. Certainly any such sediment is decidedly objectionable, but it would be caused just the same if antimony were not used, if old decayed rings were retained in use. No doubt sufficient care has not always been taken to see that decayed rings are replaced by new ones, and if this is remedied the commotion caused cannot be considered as altogether superfluous. Of course the use of antimony sulphide as a vulcanizing and colouring agent is not absolutely essential, and it could be dispensed with if the indictment brought against it could stand the test of cross-examination.

India-rubber gloves have long been used by surgeons, but of late years a greatly increased demand has arisen in connection with electrical engineering. In a recent trial the judge expressed surprise that the use of such gloves by men engaged in dangerous electrical work is not compulsory, and it was suggested that the matter required

legislative intervention. Quite a number of improvements have of late been suggested in connection with these gloves, the important matter of ventilation coming up for particular notice. The ordinary surgical rubber gloves are usually made from cut sheet rubber, the joints being secured by a narrow strip of rubber solutioned on, vulcanization being effected in the sulphur bath. A different process is followed by the Lindsay Rubber Co., of New York; in this the glove is made in the seamless state from rubber solution, being built up of two or three layers, some of pure and some of compound rubber.

An insignificant article, the umbrella ring to wit, is made in such large quantities that it is really surprising where they all go to. As strength is a prominent requisite in these articles, they are all made up by hand after a particular manner, of which the following is a brief description. Strips of spread sheet, consisting of pure rubber and sulphur, are cut into short lengths with oblique ends, giving the form of an elongated lozenge. These are wrapped round a mandril, and the edges firmly pressed together to form a perfect tube, in which the line of junction takes an oblique direction. The workgirl then rolls the tube backwards and forwards with her fingers until it takes the form of a ring, in which the original jointing line forms part and parcel of the rubber mass so perfectly that it does not constitute an inherent source of weakness. The rings are subsequently laid in a tray of French chalk, and vulcanized in the steam pan.

The vacuum jar ring, which, like the umbrella ring, has a circular cross-section, is made by a less laborious process. As it has not to undergo tension when in use, the strength

of the joint is not a matter of great importance, and the rings are made from cord rubber, which has been produced in the tubing machine. A piece of the cord has its ends cut obliquely and joined up by pressure, vulcanization being effected in steam on a bed of French chalk.

India-rubber Toys.—The great bulk, if indeed not all, of the galaxy of the rubber toys coloured or plain which are to be seen in the shop windows come from the Continent, France and Germany having long been the principal producers, though Russia has recently entered the field. The business has never recommended itself to the large British and American factories: for the weight of rubber turned out, there is a good deal of trouble in providing a variety of moulds, the toys all being made of compounded rubber and being shaped and vulcanized in specially designed moulds. The French seem to have started the manufacture first, possibly getting the idea from the animal and other shapes in which the Para rubber of the early days of the industry was exported. In 1876 some commotion was caused in Germany by the death of a child from sucking a rubber toy imported from France, and the German doctors having discovered that zinc oxide was poisonous, got a decree passed forbidding the importation of French rubber toys into Germany, The French saw in this an adroit move on the part of the Germans to efface competition, and they were not wrong, for the manufacture was shortly started in Germany without any particular attention being paid as to what chemicals were used. Meanwhile, the French Minister of Agriculture and Commerce appointed a committee, who found that zinc oxide was perfectly harmless, but that several of the colours used in painting the toys were

poisonous. Of these colours, white lead, Prussian blue, Scheele's green (arsenite of copper), chrome yellow and vermilion were barred from further use on toys by a decree of the Prefect of Police in 1878, and although some modification was made in a further decree of 1884, it may be taken that poisonous colours are not now to be met with on French rubber toys, and in this respect the law is now much the same in Germany. In the latter country, moreover, although the indictment of zinc oxide has been abandoned, it is forbidden to use lead oxides, barytes, or other more or less poisonous chemicals in the body of the rubber.

Rubber in the Chemical Laboratory.—India-rubber corks and gas tubing are in common use by the analyst, and a word or two about them may not be without interest. The original rubber cork consisted of natural cork, either treated with rubber solution or having a film of sheet rubber attached to its surface. These belong to the domain of history, laboratory corks of the present time consisting of compound rubber vulcanized in moulds, the red ones containing antimony pentasulphide being the best quality. Periodically, some chemist writes to the *Chemical News* or other journal drawing attention to the fact that he has discovered free sulphur in these corks and that it may easily lead to errors in work. This is certainly the case, and where these corks are used in extraction apparatus with alcohol, acetone or other sulphur solvent, the precaution of boiling them in caustic alkali should always be taken. Constant exposure to high temperature will cause hardening and decay after a time, while the vapours of ether and hydrocarbons will induce swelling and subsequent disintegration, which may cause particles of mineral matter to be

removed. Examination should, therefore, be made from time to time and defective corks be replaced by new ones.

With regard to rubber gas tubing, this is sold at prices to suit all purses, though it must be confessed that the sale of tubing containing so much mineral matter that it will hardly bend is a practice that calls for strong disapprobation. Fires, and in one case at least loss of life, have resulted from such tubing breaking from its connection with the gas supply. The very best, and of course the most expensive, tubing is made of Para rubber and sulphur only; this, after being desulphurized, is almost black in colour. Perhaps of equal merit is the red tubing containing only pentasulphide of antimony as mineral matter. The black tubing is sometimes vulcanized in the sulphur bath, and occasionally in the bisulphide of carbon and chloride of sulphur liquor, though the latter process is much too risky to be recommended. These processes are only employed when tubing is made from pure sheet rubber by joining up the edges of a strip over a mandril. Although the greatest flexibility is shown by the purest rubber, experiments have shown that with regard to the passage of coal gas through the pores of the rubber, the compounded rubber acts better than the pure. It has been mentioned elsewhere that rubber will transmit gases, and it is not difficult to appreciate that mineral matter in moderate quantity will lessen the tendency of coal gas to diffuse through rubber tubing.

Hot-water Bottles.—A recent assize trial in which damages were claimed by a patient for injury received from the bursting of a rubber hot-water bottle, brought this article into prominence. Without going into the details of the

case, it was made apparent from the analysis of the rubber that it was of very inferior quality, though this, of course, might not have been within the cognisance of the unfortunate chemist who was mulcted in damages. It has been urged in another chapter that the cheapening of rubber goods, owing to competition, is a most reprehensible practice in the case of medical requirements, where any defection may be attended with momentous consequences. The defective bottle in the case mentioned was no doubt worth the money paid for it, but, being sold as a hot-water bottle, it carried an implied though probably not expressed warranty that it would stand hot water. Not unnaturally, the sequel to the case mentioned has been the demand by the retailer of a warranty from the manufacturer, a demand which is readily complied with where the purchaser is willing to pay for good quality material and not an article produced at cut prices. Pure rubber is by no means called for ; a considerable amount of mineral is admissible, but the rubber present must be of sound quality. There is nothing which calls for special notice in the manufacture ; the cotton cloth faced with rubber on both sides on the spreading machine is cut into pieces of the necessary shape and jointed with strong bands of the same material. When the naphtha of the jointing solution has quite evaporated, the bottles are put into a tray containing French chalk and vulcanized in the steam pan. They are also vulcanized sometimes in the dry heat chamber, but whatever process is adopted, precaution must be taken not to "tender" the fabric, as it is on this that the power to withstand the pressure of the hot water depends. An excess of sulphur in order to promote rapid vulcanization is no drawback to the finished goods,

more especially when they have a loose outer cover of textile material put on them.

Air proof goods, such as invalid beds and cushions, are still made after much the same manner as in Hancock's time. It is the exception, rather than the rule, to vulcanize the rubber, which is composed of about ten coatings of Para rubber put on the cotton cloth on the spreading machine.

CHAPTER XVI.

INDIA-RUBBER PROOFED TEXTURES.

As we have seen in the introduction, the art of waterproofing cloth with rubber formed the subject of some of the earliest patents in connection with the trade, the earlier attempts in this direction being improved by Macintosh to such an extent that his double texture waterproof cloth came into very general use. The machinery, however, used for the first fourteen years in the Manchester factory was by no means efficient, and a great advance was made when Hancock patented his spreading machine in 1837. The machine in ordinary use at the present time differs only in some points of detail from that patented by Hancock, and only three modifications of it have been introduced of recent years which call for notice. The rationale of the spreading process, expressed in a few sentences, is as follows :—

The cleaned rubber, either pure or mixed with sulphur and mineral matters, according to the purpose for which it is required, is rolled out into very thin sheets on what are called immersing rollers. The name is not particularly appropriate, because the actual immersion does not take place until the next operation. This consists in putting the rubber sheets into naphtha contained in zinc-lined wooden boxes fitted with lids. Here, after a time, it assumes the form of an emulsion, technically termed " dough," which is

mixed to a uniform mass on dough rollers if stiff, or if semi-liquid in a pug-mill. When working it on the rollers the operative soaps his hands to prevent the adherence to them of the sticky rubber mass. The dough then goes to the spreading machine, which consists of a horizontal roller supported on an iron frame which forms the upper end of a steam chest made of rivetted iron plates. Above the roller along its length is an iron gauge capable of being raised or lowered according to the thickness of the rubber coat required. The dough is placed by the workman by hand or with a spatula on the cloth, which is made to pass between the roller and the gauge, a thin coating of rubber being thereby put on the cloth, the naphtha being evaporated off as the passage over the steam chest is continued. The cloth then passes on to a box roller underneath the machine. The general arrangement of the machine is shown in Fig. 16.

Even in the comparatively thin coat of rubber which is revealed by the dissection of a macintosh, there may be as many as six individual coatings which go to make up the bulk. It is quite unusual, moreover, for all these coatings to consist of the same rubber. A common procedure is to fill up the pores of the cloth, especially if it be a black one, with a first coating made of pure rubber and lampblack. On this a number of coats of "body" are spread, this being of compounded rubber; a "surface" coat of still another composition being then applied to the whole. Cloth coated with rubber in this way is known as single texture; for double textures two of such cloths are passed through the doubling machine, consisting of a pair of smooth rollers, so that the rubber surfaces unite. In making these double textures the two single textures which are united may be of the same

sort, or one may be merely a lining with a thin coating of rubber spread on it to facilitate adhesion to the thicker coat on the other piece. By this means various textile materials are rendered waterproof, modern practice embracing cottons, wools, unions of cotton and wool called paramattas, and also silks, the present day business in waterproofs having a much wider scope than in the old days when a macintosh

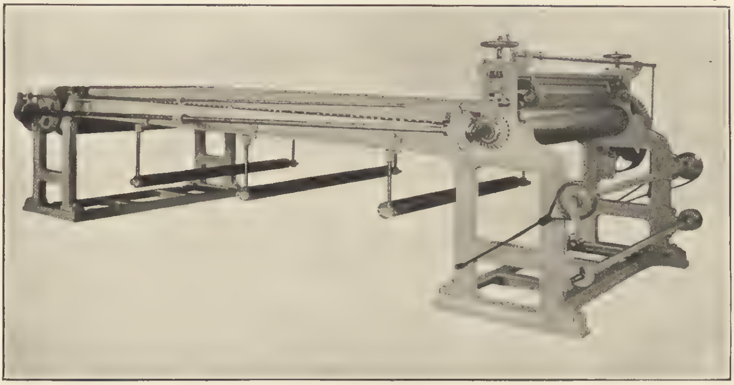

FIG. 16.—SPREADING MACHINE.

meant a heavy, black, somewhat evil smelling garment. To proceed, however, with the manufacture: the advantages which the discovery of vulcanization conferred upon the rubber manufacture were early appreciated in the waterproofing branch, where the effects of heat and cold upon the goods had led to widespread complaints. Up to 1884 the form of vulcanization mostly adopted was the Parkes cold-cure process, the cloth being passed over a wooden roller revolving in a trough of liquor, which consisted, generally speaking, of one part of chloride of sulphur in forty of carbon bi-sulphide. The evaporation of the chemical vapours was

completed by passing the cloth over a hollow drum steam heated, the material being then rolled up and sent to the cutting department of the factory, or sold in the rolls to other firms who made it up into garments. This vulcanizing process, which used to be carried out without any hygienic precautions for the benefit of the workpeople, was a very disagreeable one for all connected with it on account of the poisonous vapours given off by the liquor. Nowadays, owing to the powers possessed by the factory inspectors, a considerable amelioration of the workmen's lot has been effected. Boxing in of the cold-cure machines, and the provision of adequate ventilation whereby the vapours are removed from the work-room, represent in general the methods of reform. So far not much has been done in the way of condensing the carbon bi-sulphide fumes, though it is interesting to note that at the works of the Northern Rubber Company, at Retford, the vapours have been passed up a coke scrubber containing an absorbent liquid with results which are reported as very satisfactory.

This vulcanization process not infrequently leads to fires, which, as a rule, are smothered out with wet blankets kept in readiness, without the aid of any outside fire brigade being requisitioned. Carbon bi-sulphide will ignite by contact with hot metal, but the usual cause of conflagration is an electric spark caused by friction of the cloth, a high barometer and a dry state of the atmosphere being predisposing conditions.

Twenty-five years ago some little excitement was caused in the trade by the production by a firm of what were somewhat fancifully termed "electric" waterproofs. At this time of day it is not giving away any secret to say that the

"electric" effect was produced by merely sprinkling the surface of a single texture proof with farina powder before being cold cured.

As chloride of sulphur in contact with moisture tends to decompose with the formation of hydrochloric acid, it is usual in order to destroy any traces of acidity to expose the cured cloth to the vapour of ammonia, an operation involving very little extra expense or trouble. Stoving in a moderate heat is often resorted to in order to dissipate traces of chemical vapours which cause the proofed cloth to smell. This is not, however, very effective, and it is better to use a purified naphtha for dissolving the rubber where comparatively odourless results are aimed at.

So much for the curing process used almost universally up to 1884. At this date Waddington patented his Dry-Heat vulcanizing stove, which has since been very generally adopted for double textures, the rubber proofing having been found to withstand heat and cold to a much greater degree than was the case with the older process, though this, it must be understood, is by no means extinct, finding still very general use for thin single textures, especially those which have been colour printed and which are too delicate to stand the heat of the stove. Theoretically Waddington's patent involved no new principle in the treatment of the rubber. It was merely the adaptation of the well-known sulphur vulcanizing process to proofed cloth. In the cold-cure process there is, of course, no necessity to have any sulphur in the rubber, but in the dry-heat method sulphur has to be incorporated with the rubber, this being spread in the usual way. The roll of proofed cloth is then taken to the stove, which consists essentially

of a wooden cased-in structure heated by steam coils, and containing a large number of metal rollers about 6 inches diameter over which the cloth passes at a uniform rate of speed. The time taken in the passage of the cloth through the stove varies according to the amount of sulphur present and the temperature, the latter point having to be carefully considered in relation to the particular textile material. To give an instance, a good paramatta will stand 275° F., while a common one, with a preponderance of cotton over wool, must not be exposed to a greater heat than 260° F., about as low a temperature as can be employed for vulcanization. A good excess of sulphur has to be used in dry-heat mixings, because so much is volatilized during the process. This is rather a weak point, for not only is there the waste of sulphur, but the vapours tending to crystallize again in the stove at inconvenient spots have to be removed by a fan, and this causing cold air to enter the stove gives rise to inequalities of temperature and an increased steam consumption.

Vulcanizing in steam is sometimes resorted to in the case of proofed cloth, but this is employed more for bed and ground sheetings, etc., which contain a heavy proof on white duck, than for cloth intended for waterproof garments. Black surface single textures are, however, usually vulcanized in steam wrapped round a drum, and it is probably to this satisfactory process that such material owes its lasting powers, though the water polish containing shellac with which it is finished, must also be considered a safeguard against oxidation. With regard to the relative advantages of the cold-cure and dry-heat processes, much might be written, but for the purposes of this volume it

will suffice to say that good work can be turned out by both of them, and that where the business is in incapable hands less bad work will be turned out by the dry-heat process than by the other. The latter is by no means as simple in its action as it is expeditious in its application, and a general ignorance of the theoretical principles involved has in the past led to heavy losses from bad work.

About ten years ago the system of printing designs upon the single texture proofs was introduced, and led to a considerable demand for the fabrics so treated. The printing is carried out by engraved copper rollers, on the lines long familiar in calico printing, the effect being produced by the impress of various metallic bronzes upon the rubber surface, which has been made of a blue, red, green, or other ground tint by previous admixture of colouring matters with the rubber. In order that the coloured bronzes should adhere to the rubber the latter used to be faced with some suitable substance, and patents for the use of such bodies have been taken out by different waterproofers. These bodies include aluminium powder, phosphate of lime or bone ash, farina, finely powdered glass, etc. As time progressed, however, it was found that this preparation of the surface was not necessary for the success of the process, and at the present time surfacing is mostly dispensed with, the printing being done direct on the rubber. Compared with what was the case five or six years ago colour printed single textures are in very small demand at the present time, feminine fashions having apparently decided against them, much to the chagrin of the waterproofers, who see their expensive plant in comparative idleness. As already mentioned, this class of proofing is always cold cured.

With regard to the double textures, probably not more than 1 per cent. of the material is nowadays cold cured, and this only because the textile material will not stand the temperature of the dry-heat stove. Of course, before the introduction of the latter process the double textures had to be cold cured. The procedure generally followed was to spread a thin coat of rubber solution on to the lining, and then by means of smooth rollers to double this on to the proofed cloth just after the latter had left the cold-cure machine. Another method is for the freshly-cured surfaces from two machines to be doubled together on central rollers. Although a considerable amount of cold curing has been done with two or three hydrocarbons as substitutes for the bi-sulphide of carbon, and no complaints have apparently been made with regard to the finished goods, yet the proofers seem in all cases to have reverted to the old procedure as being in their opinion the more satisfactory. It may be taken then that the bi-sulphide of carbon substitute has yet to be found in its application to the curing of waterproof cloth as well as for the dipping process mentioned elsewhere. It has been said above that the spreading machine in general use to-day is substantially the same as patented by Hancock. In the original machine, however, the dough roller was of iron, while to-day it is always made of semi-vulcanite, an improvement made in 1870. Other improvements in points of detail are the differential pulleys by which the speed of the cloth which is being spread can be regulated from 2 to 6 yards per minute, and the inclusion of a roller at the end of the machine which enables the cloth to be passed along the steam chest at an even rate of speed, although the diameter

of the box on which the proofed cloth is rolled up keeps on increasing. Another improvement, patented by W. Coulter, in 1888, is the bull-nosed gauge by which heavy proofings are forced more completely into the cloth than is the case with the ordinary knife edge gauge. In 1883, Coulter also patented the reversible spreading machine in which there was a spreading gauge at each end of the steam chest.

Two other types of spreading machine now call for notice. The first is the double deck machine patented by Rowley and Walmsley, in 1897, as an improvement on Walmsley's original patent. In this there are two spreading gauges and rollers at each end of the machine, the two drying tables being 27 feet long and 10 feet wide. This length of steam chest is found sufficient to expel the naphtha, and to allow of the second coating of rubber being applied at the back end of the machine as soon as the cloth which has received a coating at the front end has passed over the steam chest. A pair of calender rolls also forms part of the machine. It is claimed for these machines, in addition to the great saving in labour, that owing to the rubber being spread from alternate ends a more perfectly waterproof coating is effected. In the second machine, that patented by Frankenstein and Lyst, in 1899, the main feature is the use of a large diameter spreading roller of hard rubber, by means of which three gauges can spread as many coatings of rubber at the same time. This machine, which is now in regular work, appears from all reports to have amply borne out the statement of the patentees as to economy in working expenses, its output for the same amount of labour being greatly in excess of that of the old-fashioned type of machine. The extra

cost of this machine is largely due to the greater diameter of the rubber covered roller, and timorous manufacturers looked with increased apprehension at the loss which must ensue in the case of the naphtha taking fire, an occurrence which is by no means unknown in the industry. As, however, no such catastrophe has arisen up to date it is evident that such an eventuality is a remote one.

At the present time the macintosh trade for the million, as it existed ten or fifteen years ago, has been very largely eclipsed by the so-called rainproof cloths, which it must be confessed have solid grounds for their popularity. The average man does not need to stand about in pouring rain, and where an umbrella is also carried, as is very customary, the rainproof material which is porous is altogether a more agreeable thing than the macintosh, which does not admit of ventilation. Certainly numerous attempts have been made in the direction of ventilated macintoshes, but hardly any success at all has been recorded, and it may be taken as a truism that where air can penetrate water can do likewise. There can be little doubt that the decline of the cheap macintoshes was directly due to the absurdly low rate at which, under stress of competition, they were sold. Such goods of cheap cotton, proofed mostly with oil substitute and mineral powders, had but little power of resisting atmospheric oxidation, and they soon became worthless from a waterproof point of view. Of course the higher priced coats worn by sportsmen and proofed with almost pure rubber, hold to-day much the same position as in past decades, but the market for these is necessarily a restricted one, and the demand will not keep a factory of any size in full work. As regards the future, the outlook

seems to indicate that for the ordinary business man the rainproof cloth will continue to be in favour on account of its hygienic and lasting properties, while the more expensive goods worn in the past by those who do not carry umbrellas will receive an impetus in their manufacture owing to an increased demand from motorists. It ought also to be added that the attention which has lately been given by the manufacturers to the reduction in weight of macintoshes seems destined to bring about a reaction in the favour of these goods, as it is evident that this will go a long way to minimise the hygienic disadvantages which have been a cause of so much disfavour. With regard to the Continent, where the waterproof trade has never attained the proportions it once did in Great Britain, the French must be given the palm for artistic productions in various textile materials, especially in silks, and the Russians for sombre-looking garments in which the design and heavy build indicate the useful rather than the ornamental.

Varying somewhat in its composition from the ordinary macintosh, and considerably so in the use to which it is put, is the diving dress. These are in regular demand by the salvage companies, and also form part of the ordinary equipment of a man-of-war. They are made of double texture twill proofed with pure rubber, and are usually dry heat vulcanized. Testimony is paid to the quality of the rubber proofing by the anxiety displayed by rubber scrap merchants to get hold of the discarded ones. The neck arrangements and gauntlets of these diving dresses are made of vulcanized rubber sheet, and in some cases the makers have large tanks of water in which the goods are put to practical tests before being sold.

The making up of waterproofed cloth gives employment to a large number of hands, the bulk of them girls who serve an apprenticeship to the trade. A common complaint, which no doubt is by no means peculiar to the waterproof trade, is that as soon as a girl gets efficient she leaves to undertake the responsibilities of matrimony. The jointing of seams is effected either by pasting on a strip of cloth with rubber solution or by sewing, the latter being now often done by sewing machines run by electric motors. Although all the rubber works which have taken up the proofing branch have their own cutting out and making-up rooms, a good deal of the proofed cloth is sold in the roll to others who do the tailoring only. Since the introduction of the dry-heat vulcanization, rubber proofings in the roll have been exported for making up at their destination. A good deal has gone of late years to Madrid, a very trying climate for such material owing to the extremes of heat and cold which are experienced. Canada again has been a large customer, but owing to the rubber companies of the Dominion taking up the proofing branch, the British imports have suffered a great decline in recent years.

For this export business it is desirable that only really good material should be made, as any defects give rise to so much more trouble and expense than in the case of the home trade. "Our dry-heat vulcanized proofings are guaranteed to stand all climates" is a common form of advertisement. Where the temperatures do not run into extremes, and where there really is plenty of vulcanized rubber present, this form of notice is no doubt quite in order. But it is inapplicable to a proofing consisting in the main part of oxidized oils and mineral matters. Cases

have come under the author's notice where defective proofing has been returned to England from abroad, and investigation has shown that the poor quality of the rubber mixing has resulted in its own undoing. There was nothing which could be specifically urged against the manufacturer as a defect in workmanship, except that the rubber which was said to have undergone the dry-heat process to fit it for its duties was there in such very small amount.

CHAPTER XVII.

INDIA-RUBBER TYRES.

The amount of matter which has a legitimate claim for consideration in this chapter is so large that the selection which is imperative is by no means an easy task. An attempt, however, will be made to summarise the more important points relative to the manufacture of rubber tyres, a topic which appears to be very imperfectly understood by the great army of cyclists and motorists who buy and use them. As a prelude to the main subject, a word may not be amiss with regard to orthography. It may or may not be a matter of universal knowledge that the Americans always write "tire" where we write "tyre," and there is a widespread disposition in this country to denounce this as a flagrant instance of the Americanising of pure English. As a matter of fact, in this particular case, it is we English who are in the wrong, as our form of spelling the word has no justification at all. It is not to be found in any standard dictionary,[1] and indeed is of quite recent growth, having come in with the rise of the rubber tyre into popular favour. Without going further back into the classics, it will suffice as regards etymology to say that

[1] Certainly we have, "On her head she wore a tyre of gold" (Spenser's "Faërie Queene"), but then Spenser was notorious for invention in spelling, and cannot be taken as an authority.

"tire" is derived from the word "to tie," and means something which "ties" the rim of the wheel. Perhaps a more correct spelling would be "tier," but for the sake of euphony, no doubt, the contraction into one syllable was adopted from the first. It will be seen, then, that the Americans, instead of being to blame, are actually putting us right in what is one of the stock mis-spellings of the day. It would require some research to find out who was the culprit in modern times primarily responsible for the current English spelling, but not to be too severe on him, in the absence of his defence, it is possible that the main object was to avoid confusion with other words spelt the same way, but of totally distinct derivation and signification. Having said so much by way of protest and in self-defence, the author will continue to spell according to the English custom to save the typesetter the trouble of correcting him. Rubber tyres are not troubled with a history, and authors have therefore no need to rummage among dusty archives for their material. Solid rubber tyres, as applied to perambulators, were in use some time ago, but the early suggestion of pneumatics by R. T. Thomson, who took out a patent in 1847, met with no success, and it was not until 1889, when Dr. Dunlop, of Dublin, took out his patent, that the inauguration of an immense business took place. To give a brief account of the manufacture of the different classes of tyres, the perambulator tyre may be dismissed with the observation that it is usually made of a low quality compounded rubber passed through the tubing machine and vulcanized in iron moulds in the press. Solid cab tyres are also made in the forcing machine with a die which moulds them to the required form for attachment to the wheel.

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Fig. 17 shows a modern type of forcing machine for making solid tyres. They are generally vulcanized embedded in talc in open steam, a cover being put over them to protect

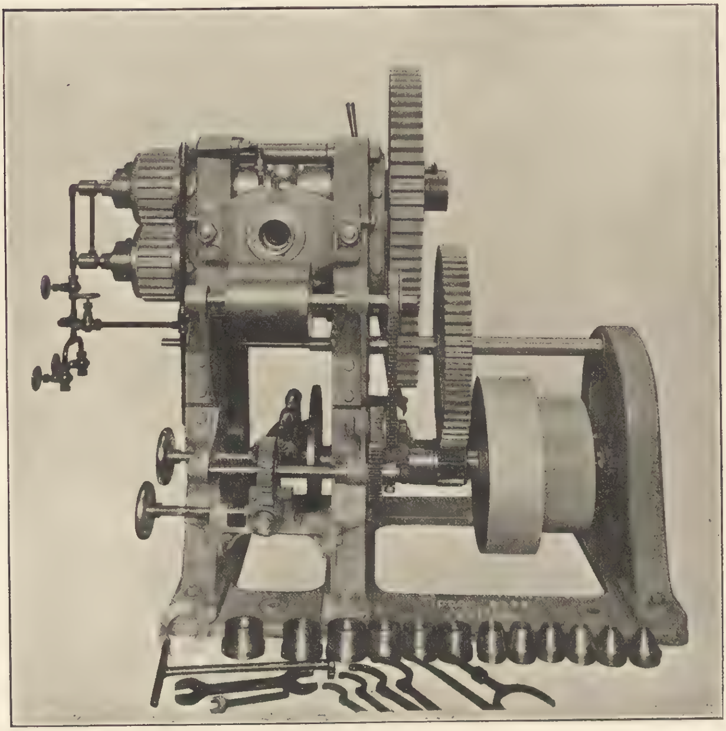

FIG. 17.—CAB TYRE FORCING MACHINE.

them from drops of condensed steam. Close attention to detail in the apparently simple operations involved are necessary to prevent porosity, or "blowing," a good deal of trouble being sometimes caused by this phenomenon, which seems to result more often from lack of official supervision

in the details of working than from any malevolent constituent of the rubber or chemicals used. Up to comparatively recent times the use of the solid tyre was confined to cabs, carriages and light motor vehicles. With the arrival, however, of the motor omnibus and merchandise vehicles, tyres of much larger dimensions of both single and twin type have come into existence, and this branch of the business, which at present is in a state of constant evolution, must assuredly in the future make a large and increasing claim upon the supply of raw rubber. As far as the principles of the manufacture are involved, these large tyres do not call for special mention, except in the use of moulds for vulcanizing, these being usually dispensed with in the case of the cab tyre.

In the ordinary solid tyre the rubber is all in one piece, but in the recently brought out Hartridge tyre it is made up of a large number of separate segments, somewhere about a hundred, each of which it is claimed acts independently, as well as collectively, for producing resiliency and an effective grip of the road's surface. A point about this tyre which should minister to economy is that a worn segment can be replaced by a new one at a trifling cost compared with what is incurred in the case of tyres in one piece. The colour of solid tyres, though usually grey, may be varied according to the ideas of the patentees or manufacturers, and will depend, of course, upon the particular colouring matters mixed with the rubber, which for solid tyres is always more or less compounded.

Coming now to the pneumatic cycle tyre, this, whatever the mode of attachment to the wheel may be, consists usually of an inner air tube of pure vulcanized rubber and

an outer cover of canvas and rubber. The mode of manufacture is as follows. The rubber is dry-mixed with sulphur upon the rollers and then calendered upon a faced sheet of cloth to the required thickness. It is then stripped and cut into bands for inner tubes and covers respectively. For inner tubes the strips are rolled over a mandril, the joint being made with solution and "rolling." A narrow strip of pure rubber tape is then placed longitudinally over the joint, the tube while still on the mandril being vulcanized in steam. After the vulcanization the joint becomes part and parcel of the tube, and effectively prevents any giving way under pressure. For considerations of appearance the tubes are turned inside out after vulcanization, so that the joint is on the inside. A good many inner tubes are also made in the seamless form by means of the tubing machine. In making the outer covers a strip of calendered rubber has another strip solutioned to its centre so as to give the extra thickness required for the tread and the desired design. This strip is then joined up to form an endless band and placed on a metal drum, the surface of which is engraved with the design for the non-slipping surface and then vulcanized. After this it is solutioned on to an insertion of linen or cotton duck, fitted with endless wires or beaded edges according to the type of tyre required, a complete outer cover thus being formed. This method was that commonly in use to produce what is popularly known as a hand-made cover, but it should be mentioned that this form of cover is now almost obsolete. The tyre cover almost universally in use at the present time is what is known as the *vulcanized* cover. The mode of manufacture is very similar to that just described, the main difference

being that the rubber is applied to the linen or canvas casing in the un-vulcanized condition, and the whole casing is fitted, with the rubber downwards, to the engraved metal drum and vulcanized. It may be mentioned with regard to the rubber strip that some manufacturers, instead of building this up from two or more pieces, obtain the necessary section by calendering a strip through bowls which have been hollowed out. The strip on issuing from the calender is carried on an endless band and cut to the desired lengths. The method of vulcanization in use at the Dunlop works has already been mentioned in Chapter IV.

During the life of the Dunlop patents considerable profits were made in this manufacture, their actual amount fluctuating with the price of the raw rubber. Now that the monopoly has run its course these profits have vanished to a great extent, and the business has little attraction except for those who can manufacture on a very large scale. As the firms engaged have their reputations to conserve, they all produce tyres made of the best material obtainable, and where second or third qualities are made to fit the needs of those of slender resources, they are sold strictly as such and on their merits. A useful plan adopted by the North British Rubber Company was to make the lower qualities a different colour from the best, so that a purchaser from a middleman could have no doubt as to what he was getting. Whether the use of the best Para rubber is absolutely necessary, or whether a blend containing a certain proportion of a lower quality gives equally good results in practice, is a matter that the several manufacturers have had under close consideration ; with such details the purchaser has no concern. It has become customary for makers to give

guarantees of lasting power with their tyres, and under the existing conditions of competition no firm will sell as best quality anything that is likely to show up badly in practice. Though the quality of the rubber is important, yet the correctness or otherwise of the vulcanization has a great deal to do with the longevity of the tyre. Whatever may have occurred in dark places, it has certainly not been customary to use reclaimed rubber in pneumatic tyres, though, in order that merit should be awarded where it is deserved, the author has cognisance of a pneumatic tyre made entirely of reclaimed rubber which was stated (from an interested source) to be eminently satisfactory. It has been sought to prevent sun-cracking or surface oxidization of tyres by admixing certain compounds containing paraffin wax with the rubber. This admixture only seems to have had a partial success, and it must not be overlooked that with every per cent. of such non-elastic matter added the proportion of rubber is reduced by the same amount. The principle underlying the use of such preservatives is, presumably, the closing up of the pores of the rubber from the insidious attacks of atmospheric oxygen, and on *à priori* grounds it should meet with success. In practice, however, other considerations are involved, and it may easily happen that the expected advantages are nullified.

When a comparison is made between the cost of different makes of pneumatic tyres, their relative weight must not be overlooked. The tendency of the present day is to use light tyres, which allow of greater speed being attained without more effort, and a pair of such tyres will naturally contain less rubber than those of more solid build. Of course, the lighter the tyre the greater the liability to

puncture, especially where the canvas is exposed, except just on the tread. It would seem that the increased use of chert—a massive form of flint—on British roads is causing a good deal of trouble to cyclists. As chert is only being used in certain districts where it can be produced locally, it would not be a bad idea for the cycling handbooks to compile some information as to the districts in which it is advisable to ride with caution. Although motor tyres will pick up chert fragments from the roads until their surface is studded with them, no very serious damage results, but in the case of the light cycle tyre the effect is often catastrophic.

Turning now to the motor tyre, which has made such immense strides in recent years, there is but little to say with regard to the manufacture of the rubber which has not been said already. No attempt will be made to enumerate the various types of motor tyres, both pneumatic and solid, which have been brought out for use on different kinds of vehicles. Evolution is proceeding at a more rapid rate in this branch of the rubber manufacture than perhaps in any other, and any exhaustive commentary would speedily require re-writing. In one direction, however, we seem likely to remain stationary, and that is with regard to the replacement of rubber by some other substance. No progress has to be reported with the various suggested applications of leather, and it does not seem that rubber has anything to fear from any of the substitutes proposed for it. For a satisfactory pneumatic tyre it is necessary to pay as much attention to the fabric as to the quality of the rubber, a point early recognised by the well-known firm of Michelin et Cie., of Clermont-Ferrand. This firm made a special study of the canvas used in their tyres, and now

weave their own from Sea Island cotton spun at Bolton in Lancashire. *Apropos* of the position attained by the firms of Michelin and the Continental Rubber Company, of Hanover, in the motor tyre trade compared with the British producers, it must be remembered that the former took up the business at an earlier date. The British firms showed a good deal of hesitancy in committing themselves to the large capital expenditure necessary for moulds, though when the use of the motor-car became as general in Great Britain as it was in France, British firms, notably the Dunlop Company, set to work at once to compete with the foreign makers of tyres. The latter had, however, already got a firm foothold, and in spite of the progress made by several home firms, they have more than sustained their position as regards the pneumatic tyre. With the solid tyre, especially those designed for omnibuses, lorries, etc., and made in the twin type, the position of British firms in the front rank is unchallenged. Of course, Continental competition has to be met, and German tyres are by no means unknown on London motor 'buses, but the situation as a whole is much more favourable to the British rubber manufacturer than in the case of the pneumatic tyre. Mineral matter enters largely into their composition, strength being of more importance than elasticity.

In the pneumatic tyres, also, although the best rubber is called for, there is no necessity to make the tyre entirely of rubber and sulphur, the addition of a small amount of zinc oxide, magnesia, or other chemical giving increased toughness, and tending, moreover, to decrease the liability to sun-cracking. The rubber which forms the tread is, it may be mentioned, somewhat heavily compounded.

Although tubeless tyres have been largely made and sold, especially in America, the pneumatic motor tyre as a rule has an inner tube, which is manufactured on the same lines as described for cycle tyre tubes. In making up the cover, when intended for vulcanizing in a mould, the strips of canvas spread with rubber solution are built up with strips

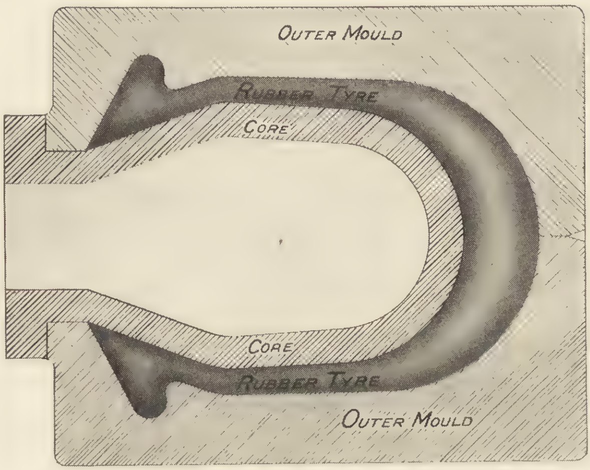

FIG. 18.—SECTION THROUGH IRON MOULD SHOWING PNEUMATIC MOTOR TYRE DURING VULCANIZATION.

of calendered rubber mixed with sulphur on a circular mandril by hand. When the tyre has been built up the mandril, or core, as it is also called, is put into the iron mould, clamped down, and put in the hydraulic vulcan press. The core, it should be said, is made in four segments in order to facilitate its removal from the tyre after vulcanization. Fig. 18 represents a section of such a tyre mould.

In the case of the solutioned tyre the rubber strips are already vulcanized before being made up; this form of tyre, though not considered so satisfactory as the other, obviates the provision of expensive moulds, and further, it has the advantage that the canvas has not had to undergo the vulcanizing heat.

Special types of tyres, of course, call for a variation in the procedure just mentioned. In the Palmer cord tyre, for instance, made by the Silvertown Company, the woven canvas is replaced by approximately straight threads or cords, each of which has a rubber coating. In this tyre it has been sought to prevent the constant friction between the warp and the weft which takes place with canvas as ordinarily woven.

In the Collier tyre, which is now made with beaded edge or mechanical fastening, special attention has been paid to reducing internal friction between the canvas and rubber. The necessity of getting these components as far as possible into a perfectly homogeneous mass has not always been sufficiently recognised, though it is difficult to over-rate its importance. Where there is not a very close adhesion between the fabric and the rubber, internal friction and consequent heating will result when the tyre is in continuous use, and it will soon become defective. It is probably not an exaggeration to say that 50 per cent. of the wear and tear of a tyre lies in the details of its construction, quite apart from the intrinsic quality of the rubber, and it is quite possible for a tyre produced at a certain cost per pound to prove less efficient and lasting than one in which the first cost of the materials was only half as much. Granting the truth of what has just been

laid down, it will be recognised that chemical analysis is of very little use in enabling us to judge of the value of a tyre as distinct from the monetary value of its component parts, and more reliable information is likely to be yielded by physical tests referred to briefly in another chapter. Of course analysis has its utility in strictly manufacturing circles, it is only from the tyre-user's point of view that its indications are apt to prove illusory.

The matter of repairs to old or damaged tyres is one of considerable and growing importance. It is often a moot point whether it is worth while to doctor up an old tyre, or whether the purchase of a new one is not the soundest policy. Where money is no object the latter course is to be recommended, both in the interests of the motorists and the trade; but as there is a large and increasing number of owners whose purses are by no means unlimited, it may be taken that the businesses of the tyre repairers, as also of the repair machinery outfitters, such as Harvey Frost and Company, will continue to flourish. By means of the vulcanizing arrangements introduced by the firm just mentioned, patches of rubber can be neatly and expeditiously vulcanized on to tubes or covers by those who do not confess to any technical knowledge of the rubber trade. Although complete unanimity does not prevail on the point, there is a general consensus of opinion in favour of the vulcanized patch as against that which has been solutioned on. The latter, especially in the case of new treads, frequently fails to be proof against the intrusion of road metal, and allows moisture to enter to the detriment of the canvas. On the other hand, where the tread is vulcanized on, it will be seen that at the point of attachment the rubber has

undergone a double vulcanization, which can by no means be considered conducive to its longevity.

With regard to the ultimate destination of worn-out motor tyres something will be seen in the chapter on recovered rubber. In some cases, however, the old tyres are doctored up with new treads, and sold again as second quality goods. Where no attempt is made to pass them off as first quality, and where the original maker's name has been removed, there does not seem much to urge against this practice. That it has not, however, commended itself to the motoring authorities is seen in the advice given to motorists, and emanating, it is understood, from high quarters, to slit up the tyres before selling them for scrap rubber.

CHAPTER XVIII.

INDIA-RUBBER BOOTS AND SHOES.

The manufacture of what are so generally known under the name of goloshes appears to have been originated by Thomas Hancock as early as 1825. These were made of pure cut sheet, the sole, sometimes of rubber and sometimes of leather, being fastened to the "uppers" by solution; they were finished off with a lining of cloth or leather. At the present time the manufacture of rubber footwear, to use the American expression, is carried out on very different lines in the numerous large factories which, especially in America, are devoted entirely to this business. The demand in Great Britain, although showing an increase in recent years, has never been a large one, and there are only three or four home firms who are engaged in this branch. Of these, by far the largest producer is the North British Rubber Company of Edinburgh, in the foundation of which American capital and energy were prominent. An increasing export trade is done with China and other countries where the golosh is largely worn. In Russia there is a large demand, more especially for the higher-priced snow boots, with or without fur tops, and other artistic developments unknown in Great Britain. The Russian and Siberian business is chiefly done by the two large home firms already mentioned as located at St. Petersburg and Riga, the high tariff being a bar to the German producers. In South-

Eastern Europe and the Adriatic littoral the author's own experience, backed by Consular reports, points to an increasing market in which American invasion is being strongly contested by the Russian houses, racial affinity and the common basis of the Slav tongues being points of vantage for the latter. The Scandinavians are the latest comers into the manufacturing field, the Norske Galoge Fabrik Aktieselskab at Mjöndalen-Drammen in Norway, and the Gummi Fabrik Aktiebolag at Helsingborg in Sweden, both being considerable producers. The latter stated its output two years ago at 5,000 pairs per day, roughly, 1,500,000 pairs per annum, a sufficiently formidable figure, although it is easily distanced by the 8,500,000 pairs per annum by the Riga-Prowodnik Company in Russia. With regard to the output of the large American concerns, it may be mentioned that the factory of the Boston Rubber Shoe Company has a daily capacity of 55,000 pairs.

In France, the Etablissement Hutchinson, a factory founded at Langlée fifty years ago by an American, has an output of 2,500,000 pairs per annum.

The manufacture, though on the face of it comparatively simple, necessitates close attention to detail if satisfactory results are to be assured. Each factory has its special formulæ for the rubber compound and varnish, and it is especially in regard to the latter that some firms have a pre-eminence in the trade. While the uppers are always made of new rubber, a commoner mixing containing reclaimed rubber is generally used for the soles. In making goloshes the compound rubber is calendered on the fabric to the required thickness and cut into the necessary shape by a knife. For the soles, special small embossing calenders are

used, whereby the pyramid or other design is put on. In a recent improvement the sole is both embossed and cut out of the sheet at the same time. The making-up is usually performed by hand on an iron mould, the necessary rubber and fabric parts for each pair being put into a separate box and handed to the workman. Quite recently the making-up has been done in some American factories by the machine patented by Doughty, though how far this is destined to replace hand labour generally is a matter which is yet in the region of speculation. The golosh having been finished on the mould, a coating of black varnish is applied, usually by hand, though a machine has recently been introduced for the purpose in America, by which it is said that the varnish is more evenly applied. Boiled linseed oil is the most important constituent of this varnish, and it is very essential that the lamp black should be quite free from greasy and resinous matters. The shoes, while still on the moulds, are run in large numbers at once on trucks into a dry-heat vulcanizing stove, the temperature and time being carefully regulated according to the composition of the rubber.

A common defect of goloshes has been their liability to come off at inopportune times, and it is of interest to note the improvement introduced by the Riga-Prowodnik Company to remedy this. A stiff back or stay is inserted in the heel, and this, in conjunction with a stud placed on the outer side, has also the advantage of allowing the shoe to be removed without the wearer having to bend down and use the hands. This is a matter of some importance in Russia, where the golosh is so universally worn, and is continually being put on and off.

The golosh, of course, is by no means the only article turned out by the rubber shoe factories. Snow boots, thigh boots, Plimsolls, Wellingtons, and so on, contribute to the output, though all the varieties may not be made at one and the same factory. With regard to Wellington boots, the specification for the Royal Gunpowder Factory limits the mineral matters to sulphur and oxide of zinc. If this requirement is really insisted on, it means a decided alteration in the usual mixing, in which litharge is always found.

In 1902, A. O. Bourne, of the United States, patented a process for vulcanizing rubber shoes in a jacketted pan under pressure, and instead of using compressed air he put in the pan a solid chemical substance which gasified under heat, thus providing the necessary pressure. It is said that by this process a great saving in the time of vulcanization is effected, and also that the value of the goods is enhanced.

Perhaps the most vulnerable part of the golosh is the heel, and a glance at patent literature shows that this matter has been by no means neglected. A few years ago the Boston Rubber Shoe Company of U.S.A. brought out the "service heel," which was made with a rolled edge and brought up on the rear as a further protection.

C. M. Berry, of U.S.A., proposed to fit the outside of the heel with hard rubber, so as to give greater durability. It was urged as an additional advantage that, as the heel was not noiseless, the wearer need not feel so much of a sneak. This point, by the way, has always militated against the increased use of the golosh in England, and if the vulcanite heels prove satisfactory one might expect an increase of business among those who have no desire to emulate the silent step of the policeman on his midnight beat.

CHAPTER XIX.

RUBBER FOR INSULATED WIRES.

In proportion to other insulating media vulcanized rubber does not hold to-day the position it once did. This is not attributable so much to the trouble caused by the defection of cables insulated with a poor quality of rubber as to the comparative economy attending the use of fibrous bodies soaked in rosin oil or vulcanized bitumen. For very high pressures, and for connections where flexibility is of importance, the vulcanized rubber cable still holds the first place, and is made to-day under more skilled supervision as regards the quality and treatment of the rubber than was at all general ten years ago. Most of the large cable manufacturers have now got rubber machinery of their own, though formerly it was more common for them to buy the rubber, both pure and compound, from the rubber manufacturers. This still obtains in several cases, contracts being placed for material to be composed according to formulæ given. The compounded rubber is sent to the cable works interrolled with cloth, the necessary vulcanization being effected on the finished cable. Three principal classes of rubber are utilised in cable making. First, the fine sheet, used as a first coating for the wire, this being either cut sheet or spread sheet. The latter is now generally used and is made from the best hard-cure Para rubber which has been "aged" for some months. If used directly after

washing and drying it has not quite the same strength. Secondly, there are the compound rubbers, concocted according to instructions received. These may be divided into two classes, one known as a separator, having little or no free sulphur, and the other containing the full amount of sulphur necessary for efficient vulcanization. Thirdly, there is the rubber-faced tape used for covering the cable. The less said about the rubber in this the better, it being as a rule composed of a poor class of rubber compound. It consists of cotton cloth having a coating of rubber put on both sides by the spreading machine. With regard to contracting for these materials, it is one thing to stipulate what is to be supplied, and another thing to see that you get it. Certainly rubber analysis has made such progress of late years that there is no particular difficulty in determining whether the pure rubber strip and the rubber-faced tape are up to requirements. The difficulty comes in with regard to the second quality rubber used for the compounds. Some cable makers specify a particular brand, say Camata or Columbian, but analysis is quite incapable of saying whether a particular brand has been used alone or in conjunction with another brand of somewhat similar nature. A great deal is made in some quarters of the resin figures for each rubber, but there are many cases where they form a broken reed to depend upon. In the present state of our knowledge there would remain plenty of room for hard swearing on both sides if a dispute as to the particular rubber used came under judicial cognisance. In a recent paper, Atkinson and Beaver[1] point out that the rate of oxidation of pure spread rubber strip of different makes

[1] "Trans. Inst. of Electrical Engineers," 1905.

varies a good deal, and it would be interesting to know if uniformity in this respect occurs regularly in strip of the same make. Besides cut and spread pure rubber strip, rolled strip is also used for electrical purposes, especially when transverse rigidity is required. In some cases in order to impart apparent toughness to the strip, it is slightly vulcanized with chloride of sulphur, an operation that requires to be carefully carried out. The presence of a small quantity of sulphur in the strip indicates the employment of this process, always supposing that the rubber is pure and does not contain any substitute. Other ways of surface hardening the freshly cut rubber strip or narrow ribbon are in use by individual manufacturers, but of these it is not proposed to say anything in detail. The same degree of reticence will be observed in regard to the finish which strip receives in order to destroy its adhesiveness, the processes employed by the several manufacturers showing considerable variation. Owing to the injurious effect of copper upon rubber, a fact referred to earlier in this volume, it is the regular custom to give the copper wires a coating of tin. This tinning may be well or inefficiently carried out, but even when done in a first-class manner, without economising in tin, it is a common thing for copper sulphide to be found adhering to the first coating of pure rubber in an old cable or in one which has broken down owing to too great an electric pressure. The explanation of this probably lies in the supposition that the tinning process does not result in merely putting a layer of pure tin upon the copper, but that a tin-copper alloy is formed which under certain conditions attacks the sulphur in the partially vulcanized rubber.

The complaints of cable makers of the front rank regarding the unfair competition they have to meet owing to the facility with which the rubber insulation can be sophisticated are doubtless perfectly justified. Possibly those who use second-class material may put forward pleas of justification which call for consideration, but whether or no, it is manifestly unfair for the municipal magnates who have the giving of cable contracts in their power to ask for first quality material, and then to give the contract on account of price to a firm whose insulation is by no means first-class. As a means of combating the effects due to this lack of discrimination, an Association of cable makers was formed a few years ago, and buyers of cables bearing a certain mark now know that they are getting the best quality. This step was certainly justified, both in the interests of the buyers and of the manufacturers of reliable insulation. If inferior cables are now bought as first-class, it must be attributed to caprice, indifference or parsimony on the part of the purchasers, who will no longer have any justification for heaping anathemas upon rubber insulation generally. Owing to the porosity of vulcanized rubber under pressure—in which respect it differs greatly from gutta-percha—it is unsuitable for submarine cables. At least this is the opinion generally, though not universally, held by cable makers. Messrs. Hooper and Company, of London, have long held a contrary opinion, and have supplied rubber-insulated cables for many years past for submarine purposes. These cables appear to have given every satisfaction, though it should be noticed that they have been mainly laid in estuaries and shallow waters and not at great ocean depths. In America the virtues of india-rubber for deep-sea work have been loudly

sung in recent years, and a considerable mileage has been laid. The rubber in this case is not lapped on by machinery, as in electric light and power cables, but is applied in a seamless state by a sort of tubing machine. The firm to whom credit is due for firmly establishing the capabilities of rubber in this connection is the Safety Insulated Wire and Cable Company (New York), whose successful use of seamless rubber insulation in the cable system connecting up the Philippine Islands led to them obtaining the contract for the Washington-Alaska cable, an enterprise of considerable difficulty owing to climatic conditions. This cable consists of a conductor of nine copper strands, having first a seamless covering of pure Para rubber, and secondly a layer of vulcanized rubber also applied in the seamless manner. Jute covering and steel armouring complete the cable, which is altogether 2,088 miles in length. With regard to transit, such cable has a great advantage over gutta-percha, as water tanks are not required. There are now about 5,000 miles of rubber-insulated cable laid by Americans, both in torrid and ice-cold waters, and at depths down to nearly two miles, so that its capabilities can be watched under varied and exacting conditions. Sceptics may say that two or three years is insufficient time in which to give a definite opinion, but at any rate it certainly seems that the threatened extinction of the gutta-percha supply may be viewed without deep concern as far as its principal application comes up for consideration.

A comparatively new use for rubber-insulated wires is in collieries and metal mines. Although the electric drill has not made much progress, electric hauling in the levels and on inclined planes is well established, a notable instance

being seen in the installation put down by a Christiania firm in the Röros copper mines in Norway. Electric winding in deep colliery shafts is in operation in Germany, and is now being introduced into South Wales, while electric pumping is taking the place of steam power to some extent in mining districts. For these purposes, where dampness is always to be apprehended, the rubber cable has good prospects, though present practice is by no means confined to this type.

A class of cable which was shown for the first time at the last Paris Exhibition under a working pressure of 25,000 volts is due to Signor Emmanuel Jona, of Pirelli and Company, Milan. This has a complete insulation of several layers of rubber, over which layers of prepared paper or jute are wound, this giving a more equable stress through the insulation.

The electrical properties of rubber insulation have been referred to in an earlier chapter, though as fibrous insulation was not included in the figures quoted it may be mentioned here that the specific inductive capacity of the diatrine paper insulation of Messrs. Glover and Company has a value of 2·8, much the same as good class rubber insulation. Altogether the progress that has been made in late years in substituting rubber by impregnated paper and bitumen hardly points to any prospective increased demand for the former in this particular application.

CHAPTER XX.

VULCANITE.

The discovery and manufacture of vulcanite, or ebonite, is almost as old as that of vulcanization itself, its initiation being due to Goodyear. The manufacture does not differ essentially from that of soft rubber goods, except that the amount of sulphur used is considerably larger—from 30 up to as much as 60 per cent. in some cases. The product is well known in the form of combs, knife handles, photographic dishes, match boxes, etc., while it finds a large application in the electrical industry and in chemical manufacturers' plant. As regards the extent of the manufacture in Great Britain, but little of a complimentary nature can be said, for both in respect of quality of goods and the output Continental countries, more especially Germany and France, have long got ahead of us, and still maintain their position. Not that the manufacture is non-existent or even moribund in this country; several of our larger rubber factories make the material, and one concern, the Scottish Vulcanite Company, of Edinburgh, is concerned entirely with it; but still, compared with our pre-eminence in most of the other branches of the industry, we hold a poor position with regard to vulcanite. This statement may conceivably be challenged, but it gains considerable

support in the returns, showing the purchases made abroad by our Government Departments. The Post Office alone bought over two thousand pounds worth of vulcanite on the Continent in 1905, and if returns could be obtained from the electrical industries generally they would bear witness in a startling manner to the amount of money which goes to the Continent in this connection. With regard to the chemical industry, vulcanite appliances, such as pumps, rods, tubes, etc., are used more particularly in the manufacture of fine chemicals for pharmaceutical purposes, a branch which has never attained in Great Britain the importance it has assumed in Germany; therefore, before the rise of the electrical industry, there was no great inducement to British rubber manufacturers to take up the branch. Another and more important point is that the manufacture, particularly as regards the polishing of the material, is by no means generally understood. The polishing of vulcanite goods is an art, and the exact details necessary for complete success must be considered even at this day to come in the category of trade secrets. But supposing that the methods followed are known to all, the cheap home labour by which the polishing of the goods has been so largely carried out in Germany in the past has not been available to British producers. At the present day the art of polishing vulcanite is not of quite the same importance as in the early days of the industry when vulcanite jewellery was so much in demand. In many cases to-day, notably for battery cells, the polishing process is dispensed with, the cost of the article being thereby greatly reduced. Of special note in the vulcanite manufacture is the firm of Dr. Heinrich Traun und Söhn, of Hamburg, in which the

Harburg Gummi Kamm Company is now absorbed. The firm recently celebrated their fiftieth anniversary, and in an interesting *brochure* showed the rise and development of this industry, with which alone they are concerned. Vulcanite is made also in Russia, Austria, Hungary, Belgium, Italy, and the United States—where the first factory, now the American Hard Rubber Company, was established over fifty years ago. With regard to the actual manufacture, which has been stated to much resemble that of soft rubber goods, each firm has it own special compounds, and products are to be met with consisting not only of rubber and sulphur, but containing in addition many of the chemical substances already mentioned in the chapter on compounding, besides others, such as resins, not there enumerated. In the mixing process it is essential that all the materials be absolutely dry, if the grave defect of porosity is to be avoided. The proportions of rubber and sulphur used depend upon the degree of rigidity required in the finished goods, in some cases a certain amount of elasticity being wanted, while in others material hard enough to be worked in the lathe is the object. Reference to the use of resins shows that the employment of Para rubber is by no means necessary; and, indeed, it was very early found that East Indian brands of rubber were most generally suitable for the manufacture. For the vulcanization metal moulds are generally used, and the lining of these with tin foil has been found an aid to the subsequent polishing. The vulcanizing pans and presses are similar to those already described, though the time required is longer, anything, in fact, from 6 to 12 hours, and the temperature may be as high as 330° F. In the polishing process the emery wheel is largely used; also

felt and other fibrous materials, alone or in conjunction with fatty matters.

With regard to the physical properties of vulcanite, atmospheric air has no oxidizing effect upon it, nor has sunlight the injurious action that it has upon soft rubber. Though impervious to electricity, it becomes charged with static electricity when friction is applied to it. In boiling water it softens, a property which is taken advantage of in the manufacture of small articles from sheet vulcanite. It is quite unacted upon by the ordinary rubber solvents, including heavy oils, while only the strongest mineral acids have any action. Exposure to a temperature exceeding 400° F. causes carbonization without any intermediate stage of sticky decomposition.

As in the case of the ordinary rubber manufacture, old and waste material comes up for use again after it has been ground to a fine powder.

The manufacture of vulcanite ornaments is not now of much importance, although it has been brought to a high degree of perfection. In this work the object to be copied or any new design is moulded in plaster of Paris, and rubber solution mixed with sulphur is put into the mould. It is customary to use bisulphide of carbon as the solvent, and to add the solution in small quantities at a time to allow of the evaporation of the solvent. When the mould is full it is submitted to steam vulcanization for about ten hours at four atmospheres pressure.

The material known as semi-vulcanite is, as its name implies, a half-way product between ordinary vulcanized rubber and vulcanite. It contains more sulphur than the former, but less than the latter, and its various grades of

plasticity depend upon the details of the vulcanization. It is in request for certain uses in chemical works; also for insulating purposes, where its capacity for being bent is of importance. A special insulating product of this kind has been brought out by Messrs. Pirelli et Cie.

CHAPTER XXI.

CONTRACTS FOR INDIA-RUBBER GOODS.

Large buyers of rubber goods, such as the Admiralty, War Office and other Government Departments, the various railway companies, and the London County Council, have their own specification forms, which are sent out to the manufacturers once a year. A common form of wording initiated many years ago by the Admiralty is as follows. The rubber must be fine Para, without any admixture of oil substitutes. In the case of the Government Departments the exact proportions and nature of the mineral matter to be used are specified, as also the proportion of sulphur. The railway companies and other corporations up to recent times usually contented themselves with specifying that pure Para must be the only rubber used. Now, there is nothing whatever to say against this procedure where Para rubber is really wanted, and where there is no rooted objection to paying the price that the market quotation of such rubber renders obligatory; but as years went on, it became increasingly evident to the rubber manufacturers that the specifications in many cases were not intended to be read seriously, or at all events, if they were, that no efforts were made by the purchasers to see that the requisitions were being complied with. It will be at once seen that this state

of affairs was all against the honest trader. Those who quoted for fine Para rubber were told that though the quality received was all right, the price was much higher than that of others who no doubt quoted for an inferior brand of rubber. In the case of the Government Departments the best rubber was really required, and if goods passed muster which were not of this standard the cause must be attributed either to supineness on the part of officials or to the inadequacy of the chemical tests adopted. With regard to some, at any rate, of the goods required by railway companies and others, it is clear that all Para rubber is not required, and that there is no intention of paying for it. Under these circumstances it is strange to find it specified for, and it can only be attributed to the ignorance or slackness of those responsible for the drafting of the specification forms. Indeed, the author was told by one official that he had inserted it because he had seen it elsewhere, and thought it looked well. Leaving out of account altogether the rather complicated question as to whether the best Para is necessary for railway mechanical goods, there can be no question as to the desirability of the purchaser insisting upon his specified requirements. If Para rubber is specified, let him see that he gets it; and if, on the other hand, he is not really particular as to quality, looking with a lenient eye upon palpable defects provided the price is low enough, it would be far better to have the reference to Para rubber deleted. This would make it plainer sailing for the manufacturer, who otherwise stands on the horns of a dilemma. By not using Para rubber he is neglecting express injunctions, while on the other hand he knows, with absolute certainty, as the heritage of experience,

that if he does use it his tender will not be accepted on account of price. This is where so much mischief is wrought in the rubber trade generally: it is such a simple matter to cheapen goods by a few pence per lb., that unless a certain standard of quality is strictly insisted upon by the buyer there is no saying to what degree of cheapening a manufacturer may not feel compelled to go in order to satisfy himself that he is in the running for a contract. "If I do not quote for a low quality, assuredly my competitor will," he soliloquises, when casting his eye over the clause of the specification referred to. So he proceeds to make and submit samples, presumably to the standard of the venerable specimen which may be inspected (through glass) at the stores of the company. These sealed samples, it must be confessed, are not really much of a guide to steer by, mere inspection affording little indication of quality. Defects in some classes of rubber goods are perceptible at once to the sight, but this cannot be said of rubber goods generally. It is axiomatic that the nearer we approach to a thing the more conscious we become of its imperfections; but in the case of inferior rubber goods disenchantment is not always the product of propinquity, and recourse to certain chemical and physical tests is necessitated. Where this cannot be done the manufacturer is obviously placed at a disadvantage, a circumstance which may easily affect the best interests of the buyer as well as his own. In these days, when the supposed secrets of the rubber manufacture are now to a very large extent public property, there seems no reason why a sample of the goods required should not be issued to any *bonâ-fide* contractor, a reasonable fee being charged for this privilege. With regard to

some sealed samples and patterns which have done duty for a considerable number of years, it is notorious in the trade that they are more suited to adorn the cases in an archæological museum. Laxity or oversight on the part of those responsible has led to their retention, though they do not at all correspond to the spirit of the specification form in current use.

With the wider spread of chemical analysis, and with the more general knowledge regarding the price of raw rubber, there has been discernible of late a disposition on the part of large buyers of rubber goods to face the matter of prices fairly, and to recognise that if good rubber is wanted, it must be paid for. Even with the price of rubber 2*s*. per lb. higher than it was five years ago, this tendency, which showed itself a few years ago, has experienced no set back. Indications are not wanting, for instance, that the reign of the cheap buffer at bed-rock prices is nearly over; it has been borne in upon the minds of the purchasers of these goods that the removal of the pieces of the buffer after it has been in use for a short time is an additional expense which should be debited to the original cost. Railway coaches, unlike Phaeton's car, are destined to run for more than one day; and it cannot be considered sound policy to make any part, or to include any fittings, of an ephemeral nature. The futility of buying highly adulterated rubber goods seems to have a more general recognition at the present time than has hitherto been the case, and this is to be welcomed both in the interests of the purchasers and as tending to the removal of a stigma which has been cast upon the trade by engineers and others who remained complacently blind to the fact that adulteration

was the inevitable and only outcome of the rage for cheapness.

For some years past growing dissatisfaction had been shown by many of our leading rubber manufacturers at the laxity with which the reference to Para rubber in specifications was regarded both by manufacturers and buyers. This culminated a year or two ago in strong representations being made to the Government departments chiefly concerned by a deputation of the India-rubber Manufacturers' Association. It was urged that as chemical tests did not distinguish between fine Para rubber and second-grade Para rubber, or any other high-grade rubber for the matter of that, the specific reference to Para rubber should be omitted and the term "best rubber" substituted. At the same time it was indisputably shown that the chemical and physical tests so long relied upon by the Admiralty were insufficient for their purpose, and did not in reality prove that only fine Para rubber had been used. As showing the genuineness of the agitation that had been aroused, it was suggested that the existing tests should be altered so that only the best rubber would conform to them. These representations met with courteous consideration, and led to important alterations in the specification form sent out by the Admiralty in the autumn of 1902. The alterations will be duly dealt with in the chapter on the testing of rubber goods, and it need only be said here that their advent has been welcomed by those who have the interests of the trade at heart. A far wider circle, the British public generally, should also regard the innovation with approval, as tending to efficiency both in the goods purchased and in the routine of contract placing.

In many cases, no doubt, the best rubber procurable is the cheapest in the long run; there are, however, cases where a cheap rubber is not only desirable, but absolutely necessary if efficiency is to be attained. The use of high-pressure steam has led largely to the substitution of rubber in packings by asbestos and other bodies which are not destroyed by heat, and where rubber is still used it is eminently undesirable to contract for it without taking into due consideration the exact temperatures to which it is to be subjected. There is more than a suspicion that sufficient care has not been taken with regard to this point in drawing up specifications for packings in which rubber is one of the components, and it would certainly seem that the opinion of manufacturers of repute might in cases of this sort be invited with advantage.

The main article contracted for by the Admiralty is the vulcanized compound rubber supplied in sheets out of which valve washers, etc., are cut at the dockyards. In the case of the War Office, the "ground sheet" is the principal article contracted for. This sheet, in which the soldier rolls himself, or which is made to serve as the floor of his tent, consists of cotton cloth faced with compound rubber, vulcanized.

In connection with Government contracts, it may be mentioned that the Departments reserve the right to inspect the work in progress, though it must be said that the official visits are neither frequent nor very inquisitorial. Inspection in the course of manufacture is also stipulated for by some of the consulting engineers in London who buy for Indian and Colonial Railways; it is not on record, however, that the young mechanical engineers who carry out this duty

do more than cut off an occasional sample to forward to headquarters.

Among other contractors who supply the rubber manufacturer with the formulæ on which he is to work are those insulated cable makers who have been already mentioned in a previous chapter.

CHAPTER XXII.

THE TESTING OF INDIA-RUBBER GOODS.

Considering the importance of this subject and the developments which it has witnessed in recent years, the author feels no hesitation in devoting a chapter to its consideration, especially as it forms a useful sequel to what has just been said about contracts. The application of chemical and physical tests to india-rubber goods, though more general at the present time than in the past, is naturally limited to such buyers as have at their disposal laboratories or testing shops. Some small purchasers there may be who submit samples to an outside analyst or consultant before concluding their purchases; but these are few in number, and the bulk of small buyers are not unnaturally indisposed to go to the expense of having analyses made, preferring rather to trust to the manufacturers' reputation and honesty.

It is not so many years ago that the test of specific gravity, or, to speak more precisely, of relative density, was the only one applied by the majority of purchasers of mechanical rubber goods, such as valves and washers. The mill engineer used to throw his valve into the water tank to see whether it floated or sank. This test was never a very satisfactory one, and it became of even less value when the advent of oil substitutes made it possible to

adulterate rubber largely without destroying its capacity for floating. There are, indeed, secluded places even at the present day where the light of modern knowledge has not yet penetrated, and where the engineer buys rubber goods on tests quite as crude and unsatisfactory as the above, though possibly not identical with it. Yet indiscriminate opprobrium should not be heaped upon the practical man who essays by simple tests to ascertain the value of his purchases. His experience has shown him, no doubt, that chemical analysis can be sadly at fault as a guide and mentor in these cases. Even the expert rubber analyst—as distinguished from the general analyst to whom such goods are often submitted—is unable to detect faulty workmanship which may lead to premature decay of the goods when in use. The analysis, indeed, may show the nature of the ingredients and their proportions to conform to a recognised standard, but it may fail to give further information which is of the utmost importance with regard to predicting the life of the goods under the special conditions of their employment. Amongst large buyers, therefore, it is now customary to supplement chemical analysis by physical tests specially devised for the purpose of ascertaining the suitability of the goods. The chief danger to be apprehended here is the adoption of unsuitable tests, particularly those which err on the side of severity. For instance, goods which are intended to be used only at normal temperatures should not be exposed to high temperatures such as are used to test the reliability of steam packings. This in a general sense; there may, of course, be cases where the expert employs the results of high temperature tests in order to corroborate figures obtained in other ways. What

it is intended to convey is a warning against the indiscriminate adoption of tests which have been specially devised for certain classes of goods to which alone they are legitimately applicable. A drawback which is often urged against chemical analysis is that the taking of the necessary samples means cutting or defacing the goods; there is also the further consideration that the part so taken may not be truly representative of the whole. The question of segregation of constituents which is here opened up is of too abstruse a nature to claim consideration in the present volume; it can only be hinted at as a possible explanation of discrepancies in figures obtained by different analysts.

In the previous chapter reference has been made to recent alterations in the Admiralty tests for rubber. The original tests which did duty for many years were one hour's dry heat at 270° F., and three hours' moist heat at 320° F. In 1902 the latter test was changed to four hours at 320° F., and in 1905 was substituted altogether by a chemical test which had already for some years been largely adopted on the Continent. As this test is one of considerable importance, it seems of interest to give the entire clause in which it occurs in the specification, which relates to what are known as A-quality goods :—

"The india-rubber is to be made of pure caoutchouc of the quality specified below, with no other ingredients than sulphur and white oxide of zinc. The sulphur is not to exceed 3 per cent., and the oxide of zinc is not to exceed 40 per cent., reckoned on the manufactured rubber. It is to be of a homogeneous character throughout, and is to be thoroughly compressed, free from air holes, pores and all other imperfections; it must contain no crumb rubber,

recovered rubber, or other treated or waste rubber, or rubber substitute of any kind. It must endure a dry heat of 270° F. for two hours without impairing its quality. The quality of the caoutchouc used must be of such a character that after it has been made up into the vulcanized and finished article, as defined above, not more than 10 parts per cent. of organic matter and sulphur calculated on the non-mineral matter present can be extracted from the rubber by boiling it for six hours, in a finely-ground condition, with a 6 per cent. solution of alcoholic potash."

The exact meaning of this test seems to have occasioned some little difficulty in the minds of those reading it hastily; but in reality there is nothing ambiguous about it, and its tenour should make itself clear to those who study it with a little attention.

If one might suggest a still further point of advance, this is in the direction of the issue of detailed instructions as to how these tests are to be carried out in the laboratory. It is quite conceivable that in the case of the heat test different opinions should be arrived at; not only should the arrangement of the air bath be identical in the case of both buyer and seller, but the exact meaning of "impairing its quality" should be given, as otherwise the deductions drawn by different observers are apt to be affected by the personal equation. Still, one must not expect perfection to be achieved all at once, and at any rate the new tests are generally admitted to be a decided advance upon the old ones, and to be in the interests of fair dealing. The idea of the tests is, of course, to cause the detection of any rubber which is not of the highest quality, and the specification as it stands at present gives much more scope to the manufacturer

who wishes in a perfectly legitimate way to get the best of his competitors. It is by no means certain that fine Para only will pass the test, and as all other rubbers are cheaper it may prove possible to make combinations as the result of careful experimenting such as will put the manufacturer who possesses himself of the golden thread in a position unassailable by his competitors.

The topics that offer themselves for treatment in this chapter are too numerous to allow of individual mention, and a selection must perforce be made. India-rubber solution, which is largely dealt with in the Carriage Department at Woolwich Arsenal, has to contain at least 18 per cent. of rubber. In addition to determining the amount of rubber present a mechanical test is made by solutioning two pieces of canvas cloth together, and then ascertaining the mechanical power required to tear them asunder. For a figure and description of the particular machine employed in this test, and for the testing of fabrics generally, the reader is referred to Weber's book on the chemistry of india-rubber. Another test in use by the War Office is in connection with indigo-blue cloth; this has to stand boiling for ten minutes in a dilute sulphuric acid solution, by which means any substitution of logwood for the more expensive indigo is at once detected. Turning now to the railway companies, it is common procedure on their part to submit samples of all deliveries of carriage and wagon buffers to mechanical tests, any failure rendering the whole consignment liable to rejection. This testing on a large scale of course takes time, and involves, in addition, the purchase of rather expensive machinery; but there is no doubt that it pays the buyer. Without going into great detail it may

be said that the buffer-testing machine is on the principle of the stamp commonly used in gold mining, five or six hammers being worked by a cranked axle and striking blows on as many buffers. The superficial dimensions of the buffer springs are carefully measured both before and after the test, which may consist of 1,000 to 10,000 blows, and which may last the whole day. A good buffer should measure the same after as before the test, though one of inferior quality, *i.e.*, wanting in elasticity or badly vulcanized, will be found to have sustained a permanent set after the test. It will be recognised at once that this test is of more value than any chemical one would be, and naturally it puts the rubber manufacturer on his mettle, as it is no easy task to get such an equality of vulcanization as is requisite. It is no doubt a fact that there are variations in the elasticity and strength of rubber which cannot be detected in the ordinary course of business. This being granted, it need cause no surprise that the tests made by the railway companies occasionally lead to the rejection of buffers which the makers had every reason to suppose were exactly similar to previous deliveries which had passed the same test satisfactorily. Special reference is made to this, because it is easy for an engineer to jump to the false conclusion that some adulteration has been practised, when nothing of the sort has been attempted. Though not exactly coming within our present subject, it may be remarked that there is a strong tendency to revert to the steel spring as a substitute for the rubber buffer whose vagaries we are now considering. The following figures were obtained by a railway company from a delivery of buffers, all supposed to be of equal quality, and they show conclusively that some variation

either in the quality of the rubber or in the method of manufacture had occurred :—

	Loss after Plates.	Loss after 10,000 Machine Blows.
	Per cent.	Per cent.
1	Nil.	50
2	,,	39
3	,,	19
4	,,	25
5	,,	10
—		
1	2	48
2	8	43
3	17	36
4	7	45

The loss after plates refers to the permanent decrease in thickness noticed after the buffers have been screwed up under pressure for a length of time between iron plates, and the percentage of loss after the machine blows indicates the decrease in lifting power, or, in other words, of elasticity. For example, a buffer which will lift a weight of six tons before undergoing the machine blows, and only three tons afterwards, shows a loss of 50 per cent. It is quite exceptional for a delivery of buffers to show such great variations as are given in the table, but the figures show the value of the test from the railway engineer's point of view. Other railway goods, such as the diaphragms used in connection with the automatic vacuum brake, hose for steam heating, etc., cannot be so satisfactorily tested, though a system of testing high-pressure steam tubing by attaching two or three lengths to steam jets, and comparing their behaviour under known

pressures, has accorded useful indications as to suitability and probable longevity. The subject of physical tests for railway mechanical rubber goods has received closer attention in America than in England; but there is a feeling among the rubber manufacturers that the prescribed tests now to be found in so many specifications are altogether too severe, and that close observance of them leads to unnecessary expense, though naturally this does not fall on the manufacturer. For instance, air-brake hose must stand a pressure of 200 lbs. for ten minutes before bursting. In what is known as the friction test, a section one inch long is taken from any part of the hose and the friction, or tenacity between the rubber and fabric, determined by the force and time required to unwind the hose, the force to be applied at right angles to the line of separation with a weight of 28 lbs. suspended from the separated end, and the average speed of unwinding not to exceed six inches in ten minutes.

There are certain classes of goods which have to withstand abrasion from contact with rough surfaces. By far the most important of such goods, as regards the amount of money involved, are motor tyres, and a good deal of trouble has been taken of late in devising a satisfactory method of mechanical testing. It is safe to say that perfection has not yet by any means been attained, but the progress made is not inconsiderable. Although the different tyre manufacturers may vary their processes in points of detail, they all, as far as the author knows, use the application of friction. At a recent motor show in Germany, a well-known German tyre was set to run continuously on broken flints, the arrangement of the mechanism being that the tyre remained stationary while the road took the form of an endless band

in continuous motion. At the large rubber works of the Russian-French Company at Prowodnik-Riga, the testing of solid cab tyres has received considerable attention. The plan generally adopted is to fix four tyred wheels to arms radiating from a central axis, in this case the tyres revolving over a fixed flint bed. It is claimed that such friction tests not only distinguish between the value of the different kinds of rubber for tyre purposes, but that they also serve to detect irregularities in the manufacture.

It would occupy too much space to discuss at length the *pros* and *cons.* of these tests; moreover, as has been stated things are really only in an initial stage. The subject, therefore, will be dismissed with the remark that continuous testing of rubber on rough surfaces varies from what obtains in practice, as the tyres which become hot on running have no time to cool down, as occurs when they run intermittently.

With regard to rubber heel pads, it is sought to get an index of their wearing capacity by the abrasive action of an emery wheel. By this means the difference between an elastic rubber and one which is heavily compounded is at once seen. The test, however, must be applied with caution and with due regard to circumstances of price. Where time allows of it, it seems on the whole preferable to make a trial on the heel of some active pedestrian.

Mention may be made of a chemical test to estimate the liability of vulcanized rubber goods to undergo atmospheric oxidation. This test, as proposed by C. O. Weber, consists in immersing a weighed strip of the rubber—for instance, a motor or cycle tyre—in a solution of hydrogen peroxide in acetone. After two days the rubber is removed, dried

and weighed, any increase in weight being due to absorption of oxygen. More recently Ditmar[1] has investigated the process and suggested an alteration in procedure, though it cannot be said that the alteration makes for simplicity or is likely to at once carry conviction to those who have looked upon Weber's method with some degree of suspicion as to its general reliability.

[1] *Gummi Zeitung*.

CHAPTER XXIII.

GUTTA-PERCHA.

There is a somewhat prevalent idea that india-rubber and gutta-percha are practically identical bodies, though this is by no means the case. Not only are the substances yielded by totally different trees, but they also show a wide divergence in their properties and it is only in rare cases that the one can replace the other. John Tradescant, an English traveller, is credited with having brought the first sample of gutta-percha to England in 1656, but it was not until 1832 that the substance really attracted any attention. This was brought about primarily by the investigations made into its occurrence and properties by William Montgomery, a British surgeon resident at Singapore, a place afterwards destined to become the headquarters of a large export industry. In a letter written in 1843 to the Medical Board at Calcutta, he details the advantages which the new body was found to possess over india-rubber for certain surgical purposes. Details of his work were shortly sent to London, and Montgomery was awarded the gold medal of the Society of Arts. Not long afterwards the botanical side was investigated by Dr. Oxley, the tree being christened by Sir William Hooker *Isonandra Gutta.* The substance at once attracted considerable attention in England and France, various

patents being taken out in connection with proposed applications. Most of these were doomed to failure as they did not take into sufficient consideration the physical properties of the substance; these properties, while rendering it eminently superior to rubber for some purposes, being at the same time a bar to its general use in cases where rubber had already established itself in an impregnable position.

Recent research has added largely to the known number of species of trees which yield gutta-percha, but the productive area has only been very slightly extended by those botanists and travellers who have made the trees a special object of search. While india-rubber has been shown to occur generally in a broad equatorial belt, gutta-percha is only to be found in a much more restricted area, the total production coming from what may be roughly described as the Straits Settlements and the Malay Archipelago; Borneo, Sumatra, the southern end of the Malaccan Peninsula, Java, the Celebes and Sulu Islands being the principal gathering grounds. Of interest in this matter of supply is the statement recently made by Dr. Sherman, of the local Forestry Department, to the effect that the gutta trees are abundant in certain parts of the Philippine islands. From his further remarks there seems little doubt that the substance has long been obtained from the Philippines by Chinese merchants who kept quiet as to its point of origin when they sold it at Singapore. It might not prove of much general interest, even if space permitted, to treat the botanical side of our subject at length, and those who are specially interested may be referred to Leon Brasse's great work and to the excellent chapters in the English

translation of Clouth's book, or to Dr. Obach's papers. It will suffice here to give the main features of the raw gutta-percha industry. The trees belong to the Sapotaceæ family the *Isonandra*, or as it is now generally called, the *Dichopsis gutta*, being a prominent species, while the *Dichopsis oblongifolium* follows it closely as regards quality of product. Full grown trees have the trunk one to two yards in circumference, though the collectors by no means limit their work to those which have attained maturity. The gutta-percha occurs as a milky latex in the bark, and is always obtained by cutting the tree down and allowing the latex to drain into receptacles placed under cuts. The latex, which is called su su in North Borneo, is coagulated by being poured into boiling water. The whole business which is in the hands of Chinese merchants and native collectors is carried on in a very wasteful and unscientific manner. Good and inferior qualities of latex obtained from different trees are indiscriminately mixed together, and very little of what comes upon the European markets can be attributed to a particular species of tree. Not that the mixing is always done haphazard, for experienced collectors know how to avoid reducing the quality of first-class material.

Owing to the destructive method of collection—for not only is the tree felled but large amounts of latex are invariably left in it to be wasted—it has long been clear that a famine is merely a matter of time. Comparatively little has been done in the way of gutta-percha plantations, and the results so far achieved go to show that the cultivation is not only hedged round with difficulties but also that, compared with rubber, a much longer time must elapse before any return is obtained from invested capital. To

the best of their ability the British and Americans who are in authority in the producing areas, have sought to grapple with the situation by putting restrictions upon the felling of the trees. But as in certain rubber producing areas already referred to, it is no use putting up prohibitory notices unless there is a sufficient police force to see that the law is respected. The great difficulty in the matter is that no alternative procedure to the felling of the trees yields results which the collectors consider satisfactory. A great deal has of course been done in recent times with regard to extracting gutta-percha from twigs and leaves by volatile solvents. When the material, however, can be got much more easily, the natives are unlikely to trouble themselves with complex chemical operations, and although the processes worked out by Serullas, Jungfleish, Ramsay, Obach, etc., worked right enough, they have certainly not proved a commercial success where they have been tried in Europe, though satisfactory results have been obtained by the Dutch Company extracting gutta-percha from leaves at Singapore. The solvent which is said to give the best results is toluol, the process consisting simply of digesting the pulverized leaves, twigs, bark, etc., in it at about the boiling point of water and in evaporating the solvent off in a current of steam, as direct distillation injures the product. The residual gutta-percha has a greenish colour owing to chlorophyll, the green colouring matter of the leaves, and is said to have been highly spoken of by experts. The process has been worked in France, but to the best of the author's knowledge is not now in operation, while the disastrous career of the British Company, formed with a large capital to work the extraction, hardly needs reference.

But whatever potentialities these extraction processes may have, it seems clear that they cannot be reckoned upon as any immediate solution of the threatened famine, and it would seem that salvation can only come through such channels as Government control. It is expected that in the Philippines regulations will be made whereby collectors will have to obtain licences and be compelled to conform to procedure calculated to prevent destruction and waste. Such efforts will assuredly be watched with interest by those who foresee a shortage of supply should any great submarine cable scheme come into existence. So much for the supply, and now a word as to the raw material as it comes to Europe. The reddish white lumps of varying size always contain chips, bits of bark and water as impurities which are removed sufficiently for common purposes by maceration in hot water after being cut into small pieces. For insulating purposes it requires a more thorough cleansing, which is carried out in a special form of washing machine in which it is both shredded and squeezed in warm water, at the bottom of which the impurities collect. It next goes to the kneading mill, consisting of a fluted shaft revolving in an iron cylinder and afterwards to a strainer where it is forced through fine wire gauze. The gutta-percha, which at the end of these processes should be free from mechanical impurities, water and air, is rolled out, cut into sheets and stored ready for use.

Gutta-percha has a specific gravity just above 1, and compressed specimens will sink in water. Chemically it consists of a hydrocarbon of the same formula as india-rubber with variable quantities, of two peculiar resins named albane and fluavile. Payen who appears

to have been the first to investigate them, gives the proportions as

Gutta	78
Albane	16
Fluavile	6
	100

According to Oudemans who investigated these bodies closely, fluavile is a soft yellow resin becoming fluid at 210-230° F., while albane is a white crystalline resin becoming fluid at 320° F. The chemistry of these bodies has recently been re-investigated by Sir W. Ramsay and others,[1] whose experiments showed the extreme susceptibility of the gutta hydrocarbon to oxidation. Of more general interest will be the following analyses of raw gutta-percha taken from among the numerous figures published by Obach:—

Brand.	Gutta.	Resin.	Dirt.	Water.
Pahang . . .	78·1	19·2	1·5	1·2
Banjer red . .	47·0	30·2	1·5	1·3
Bulongan red .	68·6	29·0	1·4	1 0
,, white .	52·2	45·4	1·5	0·9
Banjer white . .	51·8	44·1	1·8	2·3
Sarawak mixed .	55·6	40·9	1·8	1·7
Banca reboiled .	46·8	51·1	1·1	1·0

The main feature about gutta-percha which distinguishes it sharply from india-rubber, is its plasticity under heat. At a temperature about 100° F. it softens; thus if a piece is put into water which is being gradually heated, it gets more and more plastic until at about 190° F. it can be moulded or drawn out into forms which it will retain on

[1] *Jour. Soc. Chem. Ind.*, 1902.

cooling. In this respect, india-rubber as we have seen behaves quite differently, and this property alone is quite enough to dispose of any idea that they are identical. As regards the action of solvents, of acids, and of alkalies, the two substances are much the same, differences being confined to points of minor importance. Although to some extent it has a cellular structure, gutta-percha is not porous to water as rubber is, and it is this which makes it such a valuable insulator for submarine cables. Exposed to the air it rapidly undergoes oxidation, the extent to which this takes place having been shown by Miller in 1856. In the oxidized state it has the form of a hard resin, its original toughness being entirely lost. The best way to preserve gutta-percha is to keep it under water, and at any rate it should not be exposed to sunlight. Although it has many and varied applications in the arts where it is utilised by chemical manufacturers, surgeons, dentists, upholsterers, hatters, fuse makers, etc., the great bulk of the gutta-percha coming to England finds its way to the great cable works on the Thames, the golf ball manufacturers probably being the next largest consumers. For the cable manufacture, great care is exercised in selecting certain brands of gutta-percha or in mixing the different brands, so as to obtain a material of high insulating power, there being considerable differences in this respect in the various qualities. The exact procedure followed is the outcome of the experience gained by the experts engaged in the large cable factories, and comes within the category of trade secrets. With regard to the application of the insulation to the wires, this is simple enough it being applied in the melted condition to the wire core as it passes through the die of a machine very

similar to the tubing machine referred to earlier. Wires are also covered by being placed between two strips of gutta-percha, the whole being then passed between two polished grooved rollers.

The total length of deep sea gutta cables is said to be now over 200,000 nautical miles, the cost of construction being variously given as 150*l.* to 200*l.* per mile.

For the golf ball manufacture the gutta-percha has to be hardened by the extraction of its resins, this being done by soaking it in tanks of light petroleum spirit. By this means the resins can be reduced to about 2 per cent., the purified gutta then requiring a much higher temperature to soften it. The advent of the rubber cored ball has largely reduced the quantity of gutta-percha treated in this way, and a further reference to this topic will be found under the head of balata.

Compared with the compounding of rubber with mineral matter, nothing of the sort takes place in the gutta-percha manufacture. Certainly, the late Mr. Dick of Glasgow, so well known in connection with gutta-percha and balata, describes some compounds, but these contained rubber as well as mineral matter, and can hardly be called compounded gutta-percha. Then with regard to vulcanization which one author says is quite feasible, and which another says is impossible, the truth seems to be that inventive genius in several cases has produced a so-called vulcanized gutta-percha by processes analogous to those employed with rubber. The product, however, seems to have no particular value, and to the best of the author's knowledge vulcanized gutta-percha has no practical applications. In saying this, it must be on the footing of not being misunderstood. The statement just made refers to gutta-percha alone, and not to

those particular compounds into which both rubber and gutta-percha enter as component parts. Gutta-percha scraps and cuttings can of course be used up again at once as new material, no reclaiming process being required as with vulcanized rubber scrap. Old material, such as is sold off periodically by tender from the Post Office stores, depends for its value very much upon the degree of oxidation it has undergone, it being found to vary considerably in this respect. Since the introduction of the dry core paper insulation, the use of gutta-percha in the subterranean telephone circuits, especially in London, has much decreased, though the author is unable to say by exactly how much the figure of 17,000 miles computed some years ago for London has undergone diminution.

Certain compounds, such as are well known in connection with the name of Chatterton, and contain gutta-percha mixed with Stockholm tar and resin, have a large application in the insulation industry. Numerous other cements containing gutta-percha have also been devised for special purposes.

With regard to substitutes for gutta-percha, trade literature is by no means barren, but there really seems to be only one that has established itself and therefore calls for mention. This is a German invention known as Gutta-Gentsch, which has been favourably reported on by the German Post-office, and has recently had a considerable application in this country in connection with electric tramway cables. It consists of a special combination of india-rubber, pitch, and resins, and is now being made in England by the New Gutta Company, Limited. While its insulating power is said to be quite equal to gutta-percha, it does not oxidize like the latter in air, a point which is,

of course, greatly in its favour for subterranean or ærial lines. With regard to its capabilities for replacing gutta-percha in deep-sea work, it is somewhat early to speak with confidence, but it may be mentioned that a short length of deep-sea cable insulated with it was laid by Felten and Guilleaume in 1902 off the German coast.

Statistics of Gutta-percha Exports.—If any corroboration were needed of the statement previously made, that the bulk of the gutta-percha supply goes for the submarine cable manufacture, it will be found in the export statistics for particular years. Except in times when great activity is witnessed in cable-laying schemes, the annual exports of gutta-percha from Singapore amount to something between 6,000,000 lbs. and 9,000,000 lbs. In the years 1898 and 1899, however, the exports were considerably greater, owing to the large cable-making companies in England putting themselves in a position to contract for the forthcoming all-British cable from Vancouver to Australia, and also to the Germans having schemes of some magnitude on hand.

Thus the exports, in round numbers, rose from 6,000,000 lbs. in 1897 to 10,000,000 lbs. in 1898 and 16,000,000 lbs. in 1899. The destination in 1899 was:—

	lbs.
Great Britain	10,149,867
Continental Europe . . .	5,586,800
United States	441,466
	16,178,133

Since the completion of the all-British Pacific cable there have been no schemes of any magnitude, and both exports and prices have materially declined.

CHAPTER XXIV.

BALATA.

This body is perhaps better known to engineers than to other classes of the community by reason of the fact that its principal application is in the manufacture of belting for machinery. It occurs as a milky latex in the bark of certain trees of the Sapotaceous order, and although in appearance, composition, and properties, it is very similar to gutta-percha, and was at one time supposed to be identical with it, it has now for the last twenty-five years been recognised as a distinct substance. It is yielded by several species of Mimusop trees, of which it will suffice to mention the *Mimusops balata* as the principal producer. This tree is found in many equatorial regions, but to the greatest extent in Venezuela, the Guianas, and the West Indies. It is from these districts that the European market has been supplied, and at the present time the business is limited to Venezuela and the Guianas. Comparatively little of the output goes to America, and probably it is this fact which led an American author a few years ago to say that balata would find more extensive employment if it were not so scarce. Although it is not easy to give any accurate figures, owing to the fact that it is lumped together with gutta-percha in our trade returns, it is a fair assumption that the European

imports total about 1,000 tons per annum. There is no evidence that this quantity could not be largely increased if the demand was greater and a remunerative price was regularly obtainable. Outside the balata belting manufacture the applications of balata have been kept somewhat as trade secrets. How much or how little is used in the submarine cable manufacture is a matter known only to those immediately concerned, and the same thing may be said with regard to the solid gutta golf ball. The latter has, of course, been largely superseded by the rubber cored ball, and just at the date of the wholesale manufacture of the latter the author had inquiries from Venezuela as to what was wrong with the balata trade in England, as the demand had fallen off. This certainly looks as if it had been used to a considerable extent in the golf ball manufacture in the absence of evidence that any other industry employing balata has been revolutionised. With regard to its present applications, it is clear that an increasing quantity is being used in the belting trade, three new firms having quite recently started on a large scale in England, as well as others on the Continent.

To say a word or two now about the collection of the substance. In Venezuela it is the custom to cut down the tree and to let the latex run into vessels from the trunk while in a horizontal position. This procedure is said to be necessary owing to the very stagnant flow from cuts made in the bark of the living tree. Although there may be a good deal in this, we find that in the Guianas the felling of the trees is the exception rather than the rule. As Venezuela has of late years cut out the Guianas as a producer, it looks as if the felling system was the more

profitable for quick extraction and immediate profits, though, of course, it takes no thought of the morrow. Here the question arises as to how far conservative measures are necessary, even if their application were within the region of practical politics. There really seems no reason to apprehend a shortage of supply, owing to the comparatively limited demand and the well-known extent of the balata bearing forests. Under the circumstances of collection, it would be an extremely arduous matter to enforce any enactments prohibiting the felling of trees or to bring delinquents to justice. This would require police supervision on a scale which the present resources of the country would be inadequate to meet. Replanting of denuded areas might, however, be made a matter of compulsion, otherwise the greater distances which will have to be traversed by collectors as time goes on must lead to a rise in price. As it is, the merchants of Bolivar say that if the price in England falls appreciably below two shillings per pound the collecting and export cannot be carried on at a profit. Like the Brazilian rubber collector, the Venezuelan native has to force his way through the dense undergrowth of the sunless forest, where the climatic conditions frequently prove fatal even to those presumably inured to them. The usual time for collection is in the wet season—a reason which, in Venezuela, does not always adhere strictly to its description. If the season happens to be a dry one, the latex cannot be made to run at all from incisions in the bark, and the trouble thus given, even when the trees are felled, would be, of course, accentuated were the felling prohibited. The number of those engaged in balata gathering is by no means large, and this has led

to a certain independence of spirit. When not collecting on their own account, the natives hire themselves out to merchants who supply a collecting expedition with the necessary food and equipment for a sojourn in the forest. This procedure involves some risk, and it is by no means exceptional for the merchant to find himself in the awkward predicament of having lost his capital expenditure owing to the decamping of the members of the expedition to sell the product of their labour elsewhere. In the Guianas more favourable conditions prevail as the result of stable government. In Dutch Guiana the collection is regulated, a contractor paying a small sum for a permit, and hiring natives, who sell all the balata they gather at a fixed sum to the contractor. The undertaking has many risks, success depending a good deal upon the weather, as if it is too dry the water courses by which access is gained to the trees cannot be navigated by the canoes. The trees in both Dutch and British Guiana may reach as high as 120 feet, and the rational method of tapping the trunk is generally adopted. The coagulation is effected by exposing the latex to the sun's rays in shallow pans made of tinplate or of wood lined with leaves. This gives the sheet balata, while the Venezuelan method of boiling the latex in large kettles until it is of a doughy consistency gives the block balata. Both forms are familiar in the European market, the sheet being the purer of the two and commanding a slightly higher price. The wood of the balata tree is of a deep red colour, and its hardness has caused it to be in regular demand for building purposes. A good deal has been felled for timber in Trinidad, and the proposal was made some years ago to extract the balata from the bark by volatile

solvents. There are obvious difficulties in the way of doing this in such regions, but the idea has been revived in Venezuela in recent years, though with what success the author is unable to state. The yield of balata is stated by Clouth to be four pounds of dry substance from a gallon of the latex. Raw balata varies in colour from grey to brown, being sometimes red, this tint being doubtless derived from the colouring matter of the wood and bark. In the sheet form it is almost free from impurities of fibrous nature, though the block always contains small pieces of bark. Water is always present to a varying extent, also resinous bodies, which may on an average be put at 40 per cent. These resins differ a good deal from those of gutta percha, being less crystalline and of a lower melting point, and there seems little doubt that it is to them that balata owes some of its specific advantages over gutta-percha. The balata hydrocarbon has been recently investigated by Dr. W. A. Caspari,[1] who finds it identical with pure gutta-percha, so that there can be little doubt that it is to the fact of its associated resins being of a different nature that balata possesses properties not met with in gutta-percha.

Balata is soluable in the same solvents as already mentioned for india-rubber and gutta-percha, but, like the latter, the solution is slow unless heat is applied. Its specific gravity is given as 1·05. Compared with gutta percha, it is much more resistent to atmospheric oxidation, and this in addition to its greater toughness, make it much superior to gutta-percha for driving-belts. For this manufacture no special machinery is required. The washing process is carried out with ordinary rubber washing rolls, the loss where the

[1] *Jour. Soc. Chem. Ind.* 1905.

balata has been bought dry rarely exceeding 1 or 2 per cent. on sheet balata. The amount of water, it may be mentioned, is very variable, a point which should not escape the attention of those who may have contracted on the inspection of a dry sample. This remark applies especially to block balata, of which there are several qualities on the market. The base of the balata belting, as in the case of the rubber belt, is a strong canvas, this being passed through a solution of balata in naphtha, and when the solvent has evaporated, as many plies as are required are placed above one another by means of a special form of calender, the whole being sewn together with two longitudinal seams. Subsequent pressure forces the balata into the interstices of the canvas to produce a belt which is quite rigid at ordinary temperatures. According to a patent taken out by Banham some ten years ago, the belting was immersed in balata or gutta-percha solution in a strong iron vessel connected with a vacuum pump, the object being to get a better saturation of the canvas than can occur under atmospheric pressure. No vulcanization process is used for balata belting, and the cost of production is therefore small. From the properties of the substance it will be understood that these belts are not suitable for very warm climates, but for moderate temperatures in either dry or moist air they give general satisfaction, very rarely requiring to be "taken up." Balata belting has been made by the Gutta-percha Waaren und Treibriemen Fabrik of Altona 72 inches wide, and the manufacturing plant permits of 750 foot lengths being produced. It is to the numerous beet sugar factories in the country that so much of the German production of balata belting goes,

this form of belting having been found the most suitable to withstand the chemical solutions met with. It may be mentioned that the present activity in the balata belting manufacture is due to the lapse three years ago of the Dick patent.

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